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Are dairy farmers willing to pay for improved forage varieties? Experimental evidence from Kenya

Jamleck Osiemo [a,b,*], Kenneth Waluse Sibiko [a], Stanley Karanja Ng'ang'a [a], An M. O. Notenbaert [a]

[a] Alliance of Bioversity International and International Centre for Tropical Agriculture, Duduville Kasarani, Nairobi, Kenya

[b] Wageningen University & Research, Hollandesweg 1, 6706 KN Wageningen, the Netherlands

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ABSTRACT

Though improved forage varieties have the potential to supply high quality feed for livestock and optimize livestock nutrition and production, demand for them in developing countries is low. To inform interventions aiming to increase demand for the improved forages such as pricing, we assessed farmers' willingness to pay (WTP) for different improved seeds and two types of dried feed in Meru County Kenya. We used a mix of sampling strategies to recruit 356 dairy farmers into the study. We used the Becker-De-Groote Marschak (BDM) mechanism to elicit WTP, and a mixed effects model in the analysis. We find that the WTP for the forage products (except one) was below the market prices, and that the WTP differed significantly between farmers in co-operatives and those that were not. For related varieties, none is significantly superior to other varieties in terms of WTP. We also find that farmers who had prior exposure to the forages, larger farm sizes, mainly practiced zero grazing, and owned the livestock were more likely to bid above the market prices. Our results underscore the need for strategies that can lower the prices of the improved forages such as reducing the costs associated with their production, certification, storage, and transportation. Training farmers especially on the benefits of the improved traits can potentially increase the likelihood of farmers paying premiums for the improved traits, an important ingredient for the commercialization of the improved forage products at scale.

1. Introduction

Livestock play an important role in enhancing both food and nutrition security in developing countries (Herrero et al., 2013; Randolph et al., 2007). However, poor access to quality feed undermines this important role (Balehegn et al., 2020). Improved forage varieties bear the potential to supply high quality feed for livestock and optimize livestock nutrition and production (Fuglie et al., 2021). The improved varieties also have other advantages especially in reducing greenhouse gas emissions and improving the quality of soils when integrated with food crops (Paul et al., 2020). Unfortunately, demand for the improved forage seeds is low (Morrison et al., 2023), mostly because livestock farmers in developing countries either depend on rain-fed natural pastures, or conventional forages such as Napier grass or maize stalks (Creemers and Aranguiz, 2019), which are usually of low quality. Feed conservation (either as hay or silage), which can offset feed deficits during dry seasons when the quantities (quality) of natural pastures are (is) low is limited amongst livestock farmers mainly because of lack of capacity and unsuitability of some of the conventional forages for conservation (Balehegn et al., 2022). Low utilization of the improved varieties results in low forage and livestock productivity. The low productivity threaten the livelihoods and food security of millions who directly depend on livestock and put more pressure on the environment.

Some aspects of the low utilization and demand for the improved varieties can be explained by factors that hinder adoption of other agricultural technologies such as lack of awareness about the technologies, liquidity constraints, and uncertainty about yield distributions highlighted in Magruder (2018). However, some challenges might be unique to forages. For example, some farmers may consider forage production to be inferior to the production of other cash and food crops hence the preference to produce other crops such as maize to meet consumption needs. Second, most of the grasses are perennial implying that farmers do not need seeds seasonally (Mwendia et al., 2016). Third, though a lot of effort goes to the breeding of improved forage varieties,

* Corresponding author at: Alliance of Bioversity International and International Centre for Tropical Agriculture, Duduville Kasarani, Nairobi, Kenya.
E-mail addresses: j.osiemo@cgiar.org (J. Osiemo), k.waluse@cgiar.org (K.W. Sibiko), s.karanja@cgiar.org (S.K. Ng'ang'a), a.notenbaert@cgiar.org (A.M.O. Notenbaert).

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the enhanced agronomic traits may not reflect the priorities of the farmers as far as livestock feed is concerned. Unlike other crops such as maize for which several assessments on trait preference have been conducted (see for example Kassie et al., 2017; Lybbert, 2006; Mastenbroek et al., 2021), little has been done on assessing trait preference for improved forage seeds, implying that there is little evidence in the literature on whether livestock farmers consider the agronomic traits when making decisions on the forages to produce or to feed their livestock on, and whether there are traits (and varieties) for which livestock farmers are willing to pay a premium.

The aim of this study is to fill the knowledge gap on the low demand for improved forage varieties by dairy farmers. We assess demand by eliciting dairy farmers' willingness to pay (WTP) for four seed varieties and two types of dried feed in Meru County, one of the 45 agricultural counties of Kenya. A large portion of the county (mostly Imenti, Buuri, and Tigania) is well suited for both crop and livestock production. Meru County has about 180,000 dairy cows and about 250,000 beef cattle (Meru Dairy Cooperative Union, 2018). Milk production is about 7 L/cow/day, which is below that of other counties such as Kiambu County which is at 12 L/cow/day (Tegemeo and Kenya Dairy Board, 2021). One of the main challenges to dairy production in the county is poor animal nutrition (Meru Dairy Cooperative Union, 2018), which is partly caused by poor access to high quality feed especially during the dry season.

The four seed varieties we consider are *Bracharia Mulato 2*, *Bracharia Cayman*, *Bracharia Cobra*, and *Panicum cv. Mombasa*. The Brachiaria varieties were registered in Kenya in 2016, while the Panicum variety was registered in Kenya in 2021. The Brachiaria varieties are obtained through breeding, while the Panicum variety is a selection. Because there was no hay from the Brachiaria or Panicum varieties in the market by the time we conducted the study, we considered rice straws (which we dub "ordinary hay") and Boma Rhodes hay to represent inferior and superior types of dried feed respectively. Consideration of both seeds and dried feed helps us to generate evidence for two products at different stages of the value chain—demand for one can either suppress or increase demand for the other—an important determinant of commercialization. For example, Mwendia et al. (2016) notes that a high demand for dried feeds can offset demand for seeds even though the grasses are perennial, and that demand for either the seeds or dried feeds must be high to facilitate commercialization at scale.

The four seed varieties and the dried feed have distinguishing characteristics that might make farmers prefer one over another (see details in Ohmstedt and Mwendia, 2018). For example, the Cayman variety is tolerant to water logging unlike the other hybrids; the Cobra variety is relatively taller than the others and is best for cut-and-carry; the Mulato variety is resistant to spittlebug and has both high forage yield and nutritive quality (Maass et al., 2015). The Panicum variety on the other hand is like the improved Napier grass but is leafy and is tolerant to shade (Ohmstedt and Mwendia, 2018). Boma Rhodes hay is superior to rice straw in terms of crude protein content, organic matter digestibility, lignin level, and ash content—high levels of lignin and ash reduce digestibility (Gummert et al., 2019). Due to its low nutritive value, pretreatment of rice straw is necessary to enhance livestock productivity. Following these differences, we hypothesized that the WTP for the four seed varieties, and the two dried feeds will be different —the difference in WTP reflecting dairy farmers' valuation of the differentiating traits for each of the products.

We used the Becker-De-Groote Marschak (BDM) mechanism to elicit the WTP as we describe in detail in the subsequent sections. WTP is important in informing the pricing of the improved forages, enhancing understanding of the priority agronomic traits for the farmers, and providing evidence on whether farmers are willing to pay a premium for the priority traits. Such information is important when designing interventions aiming to enhance utilization, commercialization, and adoption of improved forages.

We report the following main findings. First, we find that WTP is below the market prices for all the forage products except for Panicum Mombasa when we consider farmers in cooperatives only. Second, we find that there are no price differentials across the Brachiaria varieties, meaning that when varieties are closely related, farmers might have difficulties differentiating them. This inability to distinguish varieties based on their "improvements" might explain the slow uptake of improved varieties by farmers (De Groote and Omondi, 2023), especially when the rate at which farmers learn about the varieties is lower than the rate at which the varieties are released. Third, we find that dairy farmers are willing to pay a premium for the Panicum Mombasa variety relative to the Brachiaria varieties—this might be caused by the similarities with Napier grass, the most popular forage among livestock keepers in Kenya. Lastly, we find that the WTP for the Boma Rhodes hay was significantly higher than that of ordinary hay, which is plausible given the superior traits of the former. Jointly, these results underscore the need to rethink mechanisms aiming to enhance utilization and adoption of the improved forages. WTP lower than the prevailing market prices for both the seeds and hay require innovative strategies to commercialize the improved forages at scale. As we alluded earlier, for commercialization to happen at scale, suppliers should be incentivized by high premiums (holding other things constant) to supply either the seeds or hay. Farmers are likely to pay a premium for the improved varieties when they know the benefits of the improved traits—we find that farmers who had experience with the improved forages were more likely to bid above the market prices.

Our findings contribute to the ongoing discussion on demand for (and adoption of) improved varieties in developing countries (De Groote and Omondi, 2023; Walker et al., 2015). The superior traits of the improved varieties should offset the high prices and increase demand for them. Unfortunately, adoption of the varieties for many crops including staple crops is low in the developing world (Acevedo et al., 2020; Walker et al., 2015). Though several factors explain the low adoption, still lacking in the literature is evidence on the demand for the improved traits and the trade-offs farmers make when selecting varieties. Some studies have assessed these trade-offs for other crops such as maize (Marenya et al., 2022), but evidence is particularly scanty for improved forages. To the best of our knowledge, no study has assessed the demand for various traits in improved forage varieties (and dried feed). Gonfa (2015), a study closely related to ours only assessed the demand for improved forage seeds using survey questions. We extend the evidence by using an incentive-compatible experiment to measure the demand for the seeds and dried feed. Evidence has shown that the use of experiments as the one we use accurately reveals WTP compared to approaches such as open-ended ranking (Waldman et al., 2014).

We proceed as follows. Section 2 describes the methods we used. In section 3, we present our findings. The last three sections provide discussions of the results, limitations of the study, and conclusions in that order.

2. Methodology

2.1. Sample size and sampling strategy

We used a mix of probabilistic (random sampling) and non-probabilistic sampling (purposive sampling) to recruit 356 farmers into the study. Our selection of sampling strategy is motivated by the nature of our study—production of improved forages is relevant to farmers who keep livestock and produce crops at the same time. We therefore targeted livestock farmers in the mixed crop-livestock production system in Meru County. We purposively selected four sub-counties namely Imenti Central, Imenti South, Imenti North, and Buuri, which are also the main dairy production zones in the county. Farmers in these sub-counties are more commercially oriented and are well organized partly because of the strong presence of dairy farmer cooperatives in the sub-counties. Evidence has shown that farmers in cooperatives are more likely to have better access to information, and other amenities such as veterinary services compared to non-cooperative members (Abebaw and Haile, 2013; Jitmun et al., 2020), factors which are likely to influence WTP for the improved forage varieties and dried feed. For this reason, we split our population into two strata namely cooperative, and non-cooperative farmers. For the cooperative strata, we purposively selected two cooperatives from each sub-county to adequately capture different dynamics such as number of active farmers for maximum variation and representativeness (Cash et al., 2022). The selected cooperatives were Buuri, Katheri, Kithurine, Githongo, Chure Dairy, Nyaki, Kaarithi, and Kathirune. We then randomly selected 30 farmers from the big cooperatives and 25 farmers from the smaller cooperatives—the number of farmers in the cooperatives varied from as low as 300 to as high as 9000. The selected farmers were invited to a central place for the experiment. We ended up with 215 cooperative farmers because some of the selected farmers failed to show up for the experiment. We used systematic random sampling to select non-cooperative farmers in which case we skipped three households to the next study participant. A farmer was selected if she/he practiced mixed farming (kept livestock and produced crops at the same time). The selected farmers were also invited to a central place for the experiment. A total of 141 farmers not in a cooperative turned up for the experiment.

2.2. BDM and WTP elicitation

We used the BDM mechanism (Becker et al., 1964) to elicit WTP for the seeds and the dried feed. Though the BDM mechanism generates rich information on an individual's WTP and is known to be incentive-compatible (Berry et al., 2020; Burchardi et al., 2021; Cole et al., 2020), some factors such as the literacy of the subjects can reduce its applicability in the field, and the reliability of the elicited WTP. For example, the elicited WTP can suffer from some biases mainly hypothetical bias and social desirability bias (Berry et al., 2020; Norwood and Lusk, 2011). Hypothetical bias arises when subjects have no experience with the product resulting in a significant difference in the WTP from hypothetical and non-hypothetical contexts. To minimize hypothetical bias, we used actual seeds in the environment of the farmers (Harrison and List, 2004). Because of the bulkiness of hay however, participants were directed to specific locations where they could get the hay from if they purchased it. Social desirability arises when participants bid in a manner they perceive to be desirable, to for instance the researcher (Zizzo, 2010). To reduce the effect of social desirability, we incorporated a cheap-talk script aiming to instill truth telling (List and Price, 2016). Another limitation of BDM is that participants may not understand the bidding process, the so-called game-form recognition failure (Cason and Plott, 2014). We address this by incorporating a practice round with regular soap costing a maximum of Ksh. 20 to ensure that participants understood the bidding process.

Farmers taking part in the experiment were informed about the study 2–3 days to the day of the experiment. Following this short notice, we could not overrule the possibility of liquidity constraints for some farmers when asked to make an unplanned purchase. To address this problem, participants received an endowment (a participation token) of Ksh. 400 (1 USD was equivalent to Ksh. 120 when we conducted the study), which they would also use to buy the seeds or the dried feed. However, we anticipated such an endowment to also influence WTP through the "house money effect" (Thaler and Johnson, 1990). We sought to reduce the "house money effect" using the cheap talk (List and Price, 2016). We emphasized to the participants the importance (consequences) of revealing (not revealing) their true valuation of the seeds and dried feed in the cheap talk.

Lastly, the order in which products are presented to the participants is likely to influence participants' responses through the "order effect". In our case, we did not anticipate any order effect for the seeds because the seeds are all improved, are "visually differentiable", and the names did not allude to any of them being superior to the other, unlike the case of the dried feed where the names "ordinary" hay and Boma Rhodes hay might alter farmers' perceptions and valuations of them. For example, participants may undervalue ordinary hay just because of the name, or because they think they were expected to undervalue the ordinary hay by the researcher ("social desirability effect"). We therefore control for the "order effect" for the dried feed by randomly varying the hay first presented to the farmer in addition to the cheap talk script. We also gave the research assistants instructions to stick to the information on the information sheets.

2.3. Description of the experiment and data collection

The experiment was conducted in the month of November 2022, which falls within the short rains season. However, because of depressed rains, the condition of natural pastures in Meru County at the time of the study was fair to poor (National Drought Management Authority; NDMA, 2022). The experiment was carried out by 10 trained research assistants, most of whom were able to speak the local language. The research assistants were recruited from a pool of research assistants who had worked with the research team before. The research assistants collected demographic data before the start of the experiment using an electronic semi-structured questionnaire. The aim of this arrangement was to ensure a good rapport between the research assistants and the participants before conducting the experiment. The data collection and the experiment followed the regulations by the Institutional Review Board of the Alliance of Bioversity International and CIAT (approval number 2022-IRB60), which included obtaining full consent from the participants, signing a consent form before the start of the exercise, and observing Covid-19 protocols. Consent was verbally sought—the research assistants read aloud the objectives of the study, measures to ensure confidentiality of the collected data, and the rules of the experiment to the farmers. The farmers were also informed that they would withdraw from the study at any point if they got uncomfortable but still receive the full participation token.

We started the experiment by presenting information sheets on the attributes of the seeds and hay to the participants alongside the seeds, 50 g of each variety—on average 3.2 Kgs of seed are required to plant 1 acre piece of land (Ohmsedt et al., 2018). The seeds were presented in brown bags that were well labelled. The information presented was obtained from Ohmstedt and Mwendia (2018), and from consultations with forage experts working in the county. In addition to text, the information sheets also contained images of the forages to enhance farmers' comprehension of some of the attributes. The information provided about the seeds included forage palatability, digestibility, crude protein content, tolerance to water logging, tolerance to drought, water requirement, planting density, planting depth, germination, days to first cut, time to rotation, plant height, production potential, soil fertility requirement, and adaptability to acidic soils (see Fig. 1, more details in the appendix). The information provided about the hay included hay palatability, digestibility, crude protein content, dry matter, crude fibre, lignin, neutral detergent fibre (NDF), acidic detergent fibre (ADF), ash, organic matter digestibility, and nitrogen digestibility. All these properties were well explained to the farmer in the local language. The information was presented one variety at a time after which the research assistants then read all the instructions on the bidding, emphasizing that though the participant bid for all the six products, one could only buy one product randomly drawn from a bag with six cards, each card representing each of the six products.

Before farmers bid for the products, we had a practice round with a 50 g bar of soap to ensure that farmers understood the bidding process. We followed the conventional procedure for BDM (see for example Berry et al., 2020). The farmers were asked to state the maximum price they would pay for the soap. The participants were then asked whether they were willing to adjust their bids for the soap. The bids were then adjusted (or not) based on the participants' responses. The participants were then asked to pick a piece of paper from a bag containing three pieces, each piece with a price on it namely Ksh. 5, Ksh. 10, Ksh. 15. A

Brachiaria cv. Cayman

Characteristic	Rating
Palatability	High
Digestibility	High
Crude protein content	Up to 17% (depending on soil fertility)
Tolerance to water logging	High
Tolerance to drought	Good
Tolerance to shade	Poor
Water requirement	Min. 800 mm/year
Planting density	8 -10 kg/ha, zero tillage
Planting depth	1 - 2 cm
Germination	7 – 21 days
Days to first cut	90 – 100 days
Time in rotation	25 – 30 days (wet season); 60 – 70 days (dry season)
Plant height	80 – 110 cm
Production potential	Up to 15 tons fresh material/ha every 10 weeks in rainy season
Soil fertility requirements	Medium to high
Adaptability to acidic soils	High
Resistance to spittlebug	High

Other characteristics

1. Tillered growth
2. In moisture conditions, this variety develops early and has many decumbent stems
3. Can withstand poor drainage

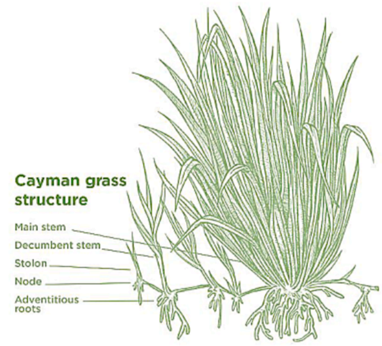

Fig. 1. Sample of the information sheet.

participant would purchase the soap if her bid was greater than the picked price—the buying price was the price picked from the bag.

Once the participants understood the bidding process, they were then asked to bid for each of the six products following the same procedure as in the practice round. This required the research assistant presenting the products again one at a time for the farmers to bid for each. The bidding was then followed by a random selection of a product to be purchased. Participants were offered a bag with six cards, each card representing each of the six products and asked to select a card. The participant was then offered another bag containing 4 prices and asked to pick a card. If the price on the card was lower than the price she bid for the product, she bought the product at the price on the card (Ksh. 150, Ksh. 200, Ksh. 250, Ksh. 300) otherwise, she did not buy the product. The cost of the product and the soap was then deducted from the Ksh. 400 participation token for the participants who purchased the forage product and the soap. The remaining amount was transferred to the participant via a mobile platform (Mpesa) at the end of the experiment. Participants who did not buy a product or the soap received the full amount of Ksh. 400.

2.4. Estimation approach

We use a mixed effects model to assess the WTP for both the seeds and the dried feed to take into account the variability of the WTP across the forage products as well as across the farmers simultaneously (Brown, 2021). In other words, the mixed effects model contains both random effects from participants, and fixed effects from the products, strata, and enumerators. The mixed effects model was executed in the R programming language as in Bates (2022). We estimate separate equations for the seeds and hay because these are two different products of the value chain though the results from the separate estimations jointly help us to draw useful conclusions. The model for the seed estimation was specified as in equation (1):

$$Bid_{iks} = \alpha + \sum_{k=1}^{4} \beta_k Seed_{iks} + \omega_i X_{iks} + S_s + E_s + \varepsilon_{iks} \qquad (1)$$

where Bid_{iks} is the bid for participant i in strata s for seed variety k, $Seed_{iks}$ is a vector of the 4 seed varieties, X_{iks} are socio-economic factors, S_s are the sampling strata (cooperative and non-cooperative farmers), E_s are enumerator effects, while ε_{iks} is an error term. Our goal in equation (1) is to test the hypothesis $\beta_k = 0$, implying that the WTP for the seeds are not statistically different from a reference variety. For the hay, we estimate two sets of equations, equation (2) and equation (3). Equation (2) includes the hay dummy (Hay_{ihs}) only. ε_{ihs} is also an error term as in equation (1).

$$Bid_{ihs} = \alpha + \sum_{h=1}^{2} \beta_h Hay_{ihs} + \varepsilon_{ihs} \qquad (2)$$

As in equation (1), the coefficients (β_h) represent the WTP for the two types of hay. In this case, we also test the hypothesis $\beta_h = 0$, implying that the WTP for the two types of hay are not statistically different. In equation (3), we include socio-economic factors X_{ihs}, sampling strata S_s, and enumerator effects (E_s) as in equation (1), and the order (O_{ihs}) dummy, which captures the order in which the information about the hay was presented. ε_{ihs} is an error term as before.

$$Bid_{ihs} = \alpha + \sum_{h=1}^{2} \beta_h Hay_{ihs} + \gamma_h O_{ihs} + \omega_i X_{ihs} + S_s + E_s + \varepsilon_{ihs} \quad (3)$$

Lastly, using the same framework, we assess the factors influencing the likelihood of farmers stating bids greater than the prevailing market prices. Our WTP in this case is a binary outcome, so we estimate a probit model as in equation (4):

$$WTP_{ijs} = \alpha_0 X_{ijs} + \gamma_h O_{is} + S_s + E_s + \varepsilon_{ijs} \quad (4)$$

where WTP_{is} is an indicator equal to 1 if farmer *j* stated a bid greater than the prevailing market price for product *i*, and 0 otherwise. All the other arguments are as in the previous equations. In this estimation, our interest is to test the hypothesis $\alpha_0 = 0$, implying that the demographic factors do not influence the likelihood of stating bids greater than the prevailing market prices. Some studies such as Berry et al. (2020) have shown that individual characteristics do not explain the individual's WTP for a product.

3. Results

We provide summary statistics of the data in Table 1. Overall, most of the participants (57.1 %) are women. Ninety eight percent of the farmers kept dairy cows, and 92 % keep livestock for commercial purposes. Most farmers (74 %) use zero grazing as their main production system. Literacy levels are relatively high—about 71 % of the farmers have above primary school education. Lastly, 33 % of the farmers earn a monthly income of more than 30,000 Kenyan shillings. We use 30,000 as a threshold because it was the most central in our income categories. The average age of the study participants is 48 years, while the average land holding is 1.95 acres. The number of years of experience in livestock production is on average 15 years.

Disaggregation by cooperative membership shows that farmers in the two strata differed in several respects. For example, 99 % of the farmers in cooperatives keep dairy cows compared to 94 % of those not in a cooperative, 87 % of those in cooperatives keep pure exotic breeds compared to 77 % of those that do not belong to a cooperative. Sixty five percent of cooperative farmers had prior experience of improved forages compared to only 31 % of the farmers not in cooperatives, a difference that is statistically significant. In addition, non-cooperative farmers were significantly younger compared to those in a cooperative. Cooperative farmers also tended to seek veterinary services more frequently than their non-cooperative counterparts.

3.1. Willingness to pay for the products by cooperative membership

We summarize the WTP for the six products by cooperative membership (Table 2). Overall, the WTP for all the products except ordinary hay are statistically different for farmers in cooperatives and those that are not. While the WTP for all the six products was below the prevailing market prices for farmers not in cooperatives, their counterparts in cooperatives were willing to pay 16 % more over the market price for the Panicum Mombasa variety. The difference between the WTP and the prevailing market was marginal (1 % less than the market price) for Mulato for the farmers in cooperatives. The biggest margin between the average WTP and the prevailing market prices were registered for the Cayman variety (25 % and 44 % of the prevailing prices for the farmers in cooperatives and those that are not respectively).

Next, we assess whether there are differences in the distributions of the bids for the various products for farmers in cooperatives and those that are not. Though participants bid more for the Panicum Mombasa variety (Fig. 2, panels A and B), the kernel density for the Panicum Mombasa does not stochastically dominate those of the Brachiaria varieties. Similarly, the density distribution of the Boma Rhodes hay does not stochastically dominate that of the ordinary hay (Fig. 2, panels C and D).

3.2. Regression analysis of the WTP

The results from the regression analysis are presented in Table 3. Models 1 and 2 are mixed effects regression results for the seeds while models 3 and 4 are results for hay. The reference (constant) in the seeds

Table 1
Summary statistics.

Variable	Description	Overall (n = 356)		Non-cooperative (n = 141)		Cooperative (n = 215)		(Cooperative vs non cooperative)
		Mean	SD	Mean	SD	Mean	SD	
Categorical variables								
Gender	1 = Participant is male; 0 = Participant is female.	0.42		0.42		0.42		1.000
Main reason for keeping cattle	1 = Subsistence; 0 = Commercial.	0.08		0.14		0.05		0.010
Education	Respondent's highest level of education: 1 = Primary level education; 0 = Above primary level education.	0.39		0.42		0.37		0.444
Important livestock type	The main livestock type: 1 = Dairy; 0 = Beef.	0.98		0.94		0.99		0.007
Majority breed	1 = Pure exotic; 0 = Others.	0.83		0.77		0.87		0.011
Monthly income	Average monthly income:1 = More than Ksh. 30,000; 0 = Less than Ksh. 30,000.	0.33		0.24		0.38		0.008
Production system	Main production system:1 = Zero grazing; 0 = Others.	0.74		0.69		0.78		0.064
Received a loan after application	1 = Yes; 0 = No.	0.96		0.92		0.99		0.257
Prior experience with improved forages	1 = Participant has planted an improved forage before; 0 = Otherwise.	0.51		0.31		0.65		0.000
Who owns the cattle	1 = Respondent; 0 = Others.	0.47		0.46		0.48		0.822
Continuous variables								
Age (years)	Age of the respondent.	48.43	13.35	46.09	14.33	49.96	12.46	0.007
Land size	Land in acres owned by the respondent.	1.95	1.71	1.77	1.56	2.08	1.8	0.098
Household size	Number of people in the household.	4.45	1.63	4.6	1.86	4.35	1.46	0.171
Frequency of seeking for vet services	Average number of times the farmers seeks for vet service in a year.	4.27	4.51	12.93	12.73	16.47	12.53	0.010
Experience	Number of years the respondent has kept livestock.	15.07	12.71	1.8	2.28	2.09	1.67	0.171
Distance to nearest market	Distance to nearest market in Km.	1.97	1.97	1.77	2.56	2.14	1.78	0.106
Distance to nearest agrovet	Distance to nearest agrovet in Km.	2.00	2.13	4.42	4.66	4.17	4.41	0.608

Table 2
Summary of WTP by cooperative membership.

		Farmers in cooperatives (n = 215)			Farmers not in a cooperative (n = 141)			
	Prevailing market price (Ksh)	Mean WTP for Cooperative members (Ksh)	SD (Ksh)	WTP – Prevailing price (% of prevailing market price)	Mean WTP for farmers not in cooperative (Ksh)	SD (Ksh)	WTP – Prevailing price (% of actual price)	P-Value WTP cooperative vs non cooperative
Seed products								
Panicum Mombasa	200	232	195.24	16	162	126.17	−19	0.000
Cayman	275	207	164.78	−25	153	106.90	−44	0.001
Cobra	225	207	170.00	−8	154	106.18	−32	0.001
Mulato	200	198	152.31	−1	159	114.75	−21	0.011
Dried feed								
Boma Rhodes hay	300	247	107.88	−18	219	124.12	−27	0.024
Ordinary hay	250	196	104.95	−22	193	108.89	−23	0.782

Note: SD is standard deviation.

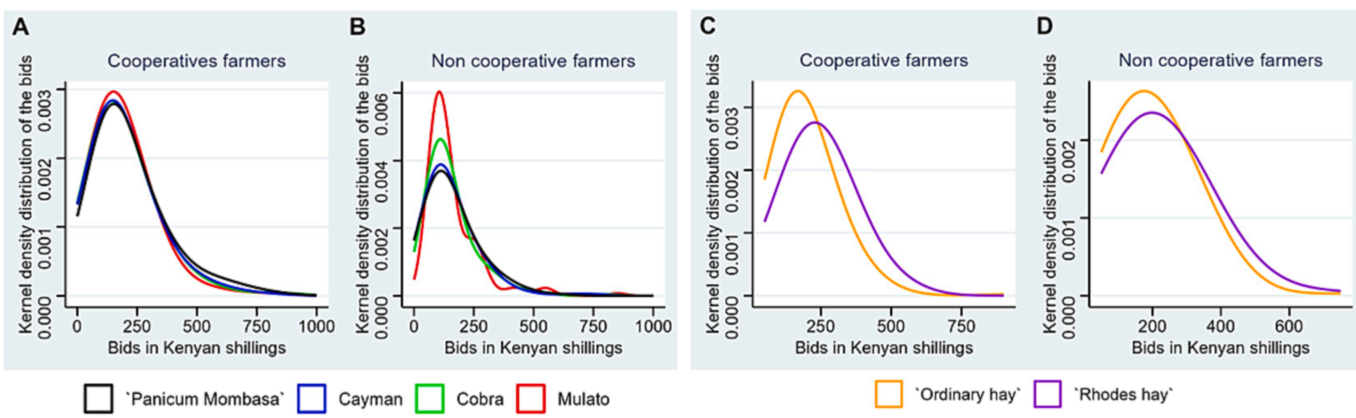

Fig. 2. WTP kernel density distributions.

Table 3
Regression analysis of WTP.

	Model 1	Model 2	Model 3	Model 4
Constant	177.284***	183.766***	194.108***	210.544***
	(27.047)	(44.894)	(7.995)	(29.903)
Cayman	3.511	3.511		
	(4.063)	(4.063)		
Cobra	3.419	3.419		
	(4.063)	(4.063)		
Panicum Mombasa	22.278***	22.278***		
	(4.063)	(4.063)		
Boma Rhodes hay			40.772***	40.772***
			(3.758)	(3.758)
Other controls	No	Yes	No	Yes
Strata dummies	Yes	Yes	Yes	Yes
Enumerator dummies	Yes	Yes	Yes	Yes
Order dummies	No	No	No	Yes
Number of farmers	356	356	356	356
Number of observations	1424	1424	712	712

Note: Significance: *** = p < 0.01; ** = p < 0.05; * = p < 0.1. Control variables included in the regression are age, education, household size, main reason for keeping livestock, land size, prior experience with improved forages, main production system, monthly income, frequency of seeking for veterinary services, and distance to nearest market.

regressions is the Mulato variety. The significant constant shows that the WTP is statistically different from zero. Models 1 and 2 show no significant difference in the WTP across the Brachiaria varieties. However, the results show a significant difference in the WTP for the Panicum Mombasa variety relative to the Mulato variety, which implies that farmers are willing to pay Ksh. 22 more on average for the Panicum Mombasa variety compared to the Mulato variety. The reference (constant) in models 3 and 4 is the ordinary hay. The results show that the WTP for the Boma Rhodes hay is statistically different from that of the ordinary hay—farmers are willing to pay Ksh. 41 more on average for the Boma Rhodes relative to the ordinary hay.

We also estimate separate regressions for seeds and hay to determine the demographic factors that influenced the likelihood of farmers bidding above the market prices (Table 4). The results in the overall column include both seeds and dried feed, while the seeds and dried feed columns show results for seeds and dried feed respectively. Across the three models, age had a strong consistent negative influence on the likelihood of bidding more than the market prices, implying that demand for both the seeds and dried feed declines with age. Land size on the other hand had a significant positive influence on the likelihood of farmers bidding above the market prices for seeds at 10 % significance level—farmers with bigger land sizes were more likely to state bids greater than the prevailing market prices. This is plausible because most of the farmers mentioned scarcity of land as the main hindrances to cultivation of the improved forage varieties (see appendix). Farmers who had prior experience with improved forage varieties tended to bid more, implying that knowledge about the varieties is important in driving demand up—this association is significant at 1 %. Practicing zero grazing as the main production system also strongly and positively influenced the likelihood of farmers stating bids greater than the market prices for both seeds and dried feed. Farmers with monthly incomes above 30,000

Table 4
Factors affecting WTP.

	Overall	Seeds	Dried feed
(Intercept)	−2.000*	−3.730**	−2.289
	(0.841)	(1.234)	(1.415)
Age	−0.050***	−0.066***	−0.067***
	(0.013)	(0.019)	(0.023)
Education (Above primary level education)	0.109	0.176	0.320
	(0.350)	(0.503)	(0.574)
Household size	0.122	0.205	0.264
	(0.102)	(0.142)	(0.167)
Main reason for keeping livestock (Subsistence)	−0.382	−0.196	−1.006
	(0.604)	(0.872)	(0.909)
Land size	0.090	0.235*	0.169
	(0.103)	(0.142)	(0.172)
Prior experience with improved forage (Yes)	1.216***	1.733***	1.188**
	(0.343)	(0.477)	(0.562)
Main production system (Zero grazing)	1.553***	2.111***	1.657***
	(0.407)	(0.603)	(0.642)
Monthly income (More than 30,000)	−0.471	−0.260	−1.610**
	(0.369)	(0.510)	(0.635)
Frequency of seeking for veterinary services	0.033	0.054	0.017
	(0.037)	(0.051)	(0.061)
Distance to nearest market	−0.040	−0.102	0.020
	(0.088)	(0.130)	(0.140)
Who owns the livestock (Respondent)	0.517	0.940**	0.316
	(0.334)	(0.471)	(0.535)
Enumerator controls	Yes	Yes	Yes
Strata controls	Yes	Yes	Yes
Number of farmers	356	356	356
Number of observations	2136	1424	712

Significance: *** = $p < 0.01$; ** = $p < 0.05$; * = $p < 0.1$.

tended to bid less for hay, a tendency that might be driven by the likelihood of these farmers having other alternatives such as producing the forages themselves. Farmers who owned the livestock tended to bid more for the seeds.

4. Discussions

In this study, we sought to assess the WTP for improved forage seeds and dried feed varieties of farmers in cooperatives and those that are not. We find that farmers in cooperatives revealed a higher WTP for the products compared to those who did not belong to a cooperative, an effect that is likely to be driven by better access to information and services as it has been shown in some studies (for example Abebaw and Haile, 2013; Jitmun et al., 2020). The low WTP (below prevailing market prices) for the improved varieties with the exception of Panicum Mombasa is a common trend also in other crops (Mastenbroek et al., 2021; Walker et al., 2015). This trend has implications on the commercialization of the improved forages value chain. As we noted earlier, farmers' willingness to pay a premium for either the seeds or the dried feed or both can incentivize more suppliers to supply the seeds or dried feed ultimately facilitating commercialization. However, our results do not depict farmers as willing to pay premiums especially for the Brachiaria varieties, which corroborate evidence in the literature (Morrison et al., 2023). This calls for innovations that can lower the costs of producing, breeding, and transporting the seeds so that market prices match farmers' WTP.

The wide margins between farmers' WTP and the prevailing market prices for the Cayman variety are plausible because the study areas are not prone to waterlogging. However, not observing a significant difference in the WTP across the Brachiaria varieties despite the differences across them such as tolerance to waterlogging (for the Cayman), tolerance to spittlebug (the Mulato variety), or suitability for cut-and-carry (Cobra) is a surprising result. Three main issues arise from this finding. First, either agronomic traits are not important criteria for improved forage variety selection by farmers as some studies have pointed (for example Macours, 2019), second, dairy farmers do not know (did not get) the differences across the Brachiaria varieties, or third, BDM as a mechanism is limited in capturing individuals' valuations of some product attributes, especially when the difference in attributes is "subtle" (see for example Ariely et al., 2003). The first two issues are an impetus to train farmers and stockists alike—evidence has shown that stockists are an important channel through which farmers obtain information about new varieties (Dar et al., 2020)—on the benefits of the improved traits, and creating opportunities where farmers experiment with the forages. The importance of farmer training is evident from our results—farmers who had experience with the improved forages before tended to bid more. Studies such as Channa et al. (2019) also show that prior awareness about a new technology influenced farmers' WTP for the technology. Simtowe et al. (2019) found that exposure to drought tolerant seeds increased their adoption by about 8 %. More research is needed on the third issue on BDM's ability to sufficiently capture individual's valuations of "subtle" but important differences across products because on one hand, the WTP for the Brachiaria varieties is not statistically different though the varieties have important distinguishing attributes, while on the other hand, the WTP for the Boma Rhodes a "superior" product is statistically different from that of the ordinary hay an "inferior" product, a clear indication of greater valuation of the superior traits of the Boma Rhodes hay by farmers. It is not clear from the literature the circumstances under which WTP sufficiently captures the valuation of the "subtle" differences across products.

The significant associations between the likelihood of farmers bidding above the prevailing market prices and some socio-demographic factors namely age of the farmer, whether farmers practiced zero grazing as the main production system, land size owned by the farmer, monthly income, and whether the animals are owned by the farmer are plausible (Beshir, 2014). The negative influence of age on the likelihood might arise because of declining interest in new technologies by older farmers, and slowness in understanding the attributes of the new technologies (Fadeyi et al., 2022). The positive association between the likelihood and land size underpins limited options to increase crop diversity for farmers with small farm sizes. Previous evidence has highlighted competing uses for land in Kenya as a major hindrance to farmers adopting cultivated forages (Maina et al., 2022). This implies that promotional efforts to cultivate improved forages should target farmers with relatively bigger farm sizes, with mechanisms in place to ensure that farmers with smaller farms have access to the forages. Cooperatives can also be used as an avenue for the promotion of the improved forages. The strong association between the WTP and whether a farmer practiced zero grazing arises from the likely dependence on cultivated forages by these farmers who mostly do cut-and-carry.

Our findings have several policy implications on the efforts aiming to promote the adoption, utilization, and commercialization of improved forages. The low WTP for both seeds and hay require innovations that reduce the costs of production, certification, and transportation of the seeds without disrupting the forages value chain. One such innovation is the promotion of farmer-led seed production through contracts, an institutional innovation that is both profitable and enhances involvement of the private sector (Mishra et al., 2016). Engaging farmers in producing the improved forage seeds is also likely to address other challenges such as access to the seeds (Maina et al., 2022), and quality of the seeds—small scale farmers usually source inputs such as seeds from the informal markets where quality of the inputs is always a big concern (Michelson et al., 2023). The arrangement is also likely to foster peer-learning, another important channel through which small scale farmers learn about new technologies (Benyishay and Mobarak, 2019; Conley and Udry, 2010; Shikuku et al., 2019). To be successful, farmer-led seed production requires an enabling legislature, for example in certification and quality assurance.

Lastly, the influence of some demographic factors on WTP implies that promotional activities could be targeted to certain types of farmers such as young farmers, farmers with larger land sizes, those using zero grazing, and those in cooperatives as we highlighted earlier. However, such an approach is likely to further marginalize farmers in the extensive production systems from the forages value chain, yet they are usually the most affected by feed scarcity, and low productivity. Therefore, the targeting should be accompanied by efficient coordination mechanisms across value chain actors to ensure that farmers who cannot produce the forages (because of limited access to land suitable for forage production for instance) are linked with farmers who produce the forages or with traders who are able to source the forages from the farmers who produce. Such a linkage is likely to create demand for dried feed, which will in turn incentivize farmers (suppliers) to cultivate (supply) the improved forages. Increased cultivation of the forages will translate to high demand for the improved seeds, and high productivity of the forages, high livestock productivity, and ultimately increase farm incomes, availability of food, and reduce the adverse impacts of the livestock sector to the environment.

5. Limitations of the study

Though the descriptive summaries of some characteristics of our sample such as the proportion of women farmers, the average household size, and the average age of the farmers are comparable to those in other studies such as Muriithi et al. (2022) and Birch (2018), our sample comprises of farmers that are relatively commercial, better educated and have better access to information and services compared to an average farmer in Meru County and Kenya in general. This limits the generalizability of our results. Therefore, more assessments comparing the WTP of farmers in different farmer segments (for example based on geography, commercialization level, and production systems) should be done for completeness. In addition, aspects such as seasonality of the forages, which we do not consider in this study should be considered in the assessments. Another limitation of our study is that like many studies, we use the standard BDM procedure without controlling for other pitfalls of the mechanism such as "anchoring" (Ariely et al., 2003), "house money effect", even though we used a cheap talk to instill truth telling to reduce its effect, and the "order effect" on the WTP for the seeds—we only conclude that there was no "order effect" because we do not see an effect on the WTP for the dried feed. Future studies assessing the WTP for the improved forages should endeavor to control for these effects.

6. Conclusion

Though improved forages have the potential of increasing productivity and addressing the rampart problem of livestock feed shortages in developing countries, poor access by dairy farmers and the high prices of the improved forage seeds hinder utilization and adoption. In this study, we have assessed dairy farmers' WTP for four varieties of improved forages namely *Brachiaria Cayman*, *Brachiaria Mulato*, *Brachiaria Cobra*, and *Panicum Mombasa*, and two types of dried feed namely rice straws and Boma Rhodes hay using an incentive-compatible experiment. Our key finding is that the superior traits of the improved forage seeds do not offset the high prices. We found big margins between the WTP for the products and the prevailing market prices despite the prevailing dry spell that would have made feed shortage more salient. We conclude that such big margins can be offset by reducing the costs associated with the production, certification, storage, and transportation of the seeds. In addition, unlike other crops such as maize and beans, the forages can be propagated through vegetative planting material, an impetus for future studies to assess the demand for vegetative material relative to seeds.

Our study also links variety specific traits to the WTP for the varieties. Our key finding in this regard is that the WTP does not reflect preference for specific traits, contrary to our expectation especially for the Brachiaria varieties which are closely related. This result implies that more awareness creation and sensitization about the benefits of the various improved traits should be encouraged to ease comprehension and decision making by farmers when selecting varieties. Furthermore, dairy farmers should be given opportunities to experiment with the various varieties—we found that farmers with prior experience with the improved forage product were more likely to bid above the market prices of the products. Comparison of WTP for Brachiaria varieties and Panicum Mombasa showed that overall, dairy farmers are willing to pay a premium albeit small (Ksh. 5) over the prevailing market price, while farmers in cooperatives (a sub-group in our sample) are willing to pay a higher premium (Ksh. 32) for the Panicum variety. We have only speculated that similarities between the Panicum Mombasa variety and improved Napier grass might be driving the high WTP. More research is needed to understand why farmers are willing to pay a premium for the Panicum Mombasa relative to the Brachiaria varieties.

Lastly, though we have data on WTP for both the seeds and dried feed, we are not able to make a direct comparison between the WTP for seeds verses dried feed first because there were no dried feed from the four varieties we assessed in the market at the time of the study, and second because these are two different types of products of the value chain, with different production dynamics. Future studies should find innovative ways of comparing the WTP for seeds and hay to shed more light on the economic feasibility of cultivated forages as a business.

CRediT authorship contribution statement

Jamleck Osiemo: Conceptualization, Data curation, Formal analysis, Methodology, Investigation, Writing - original draft. **Kenneth Waluse Sibiko:** Conceptualization, Project administration, Writing - review and editing. **Stanley Karanja Ng'ang'a:** Conceptualization, Writing - review and editing. **An Notenbaert:** Conceptualization, funding acquisition, resources, writing - review and editing.

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.

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Appendix A

	Seeds	Hay
	n = 323	n = 33
Better quality	42 (13.0)	4 (12.1)
Easily available	48 (14.9)	11 (33.3)
It is cheaper	39 (12.1)	0 (0.0)
More economical and permanent solution	187 (57.9)	2 (6.1)
Palatability	5 (1.5)	5 (15.2)
Ready to use	0 (0.0)	3 (9.1)
Scarce land	2 (0.6)	8 (24.2)

Note: Percentages in parenthesis.

Information sheets

Panicum maximum cv. Mombasa (Mombasa grass)

Characteristic	Rating
Palatability	Good
Digestibility	?
Crude protein content	8 - 14% (depending on soil fertility)
Tolerance to water logging	Low
Tolerance to drought	Good (Tropical seeds, low (SOEST)
Tolerance to shade	Poor
Water requirement	Min. 800 mm/year
Planting density	4 -5 kg/ha
Planting depth	1 - 2 cm
Germination	10 – 28 days
Days to first cut	75 – 100 days
Time in rotation	40 – 45 days
Plant height	2 meters
Production potential	20 – 40 tons dry matter/ha/year
Soil fertility requirements	High
Adaptability to acidic soils	?

Other characteristics

1. Stems do not have hair or wax
2. Suitable for grazing, silage, and fresh in feeding trough
3. Not suitable for hay due to difficult drying characteristics
4. Forage quality is excellent

Brachiaria cv. Cayman

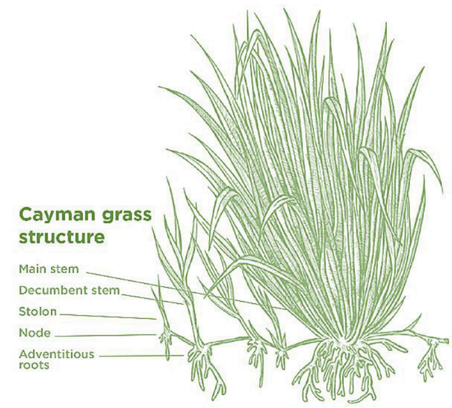
Characteristic	Rating
Palatability	High
Digestibility	High
Crude protein content	Up to 17% (depending on soil fertility)
Tolerance to water logging	High
Tolerance to drought	Good
Tolerance to shade	Poor
Water requirement	Min. 800 mm/year
Planting density	8 -10 kg/ha, zero tillage
Planting depth	1 - 2 cm
Germination	7 – 21 days
Days to first cut	90 – 100 days
Time in rotation	25 – 30 days (wet season); 60 – 70 days (dry season)
Plant height	80 – 110 cm
Production potential	Up to 15 tons fresh material/ha every 10 weeks in rainy season
Soil fertility requirements	Medium to high
Adaptability to acidic soils	High
Resistance to spittlebug	High

Other characteristics

1. Tillered growth

2. In moisture conditions, this variety develops early and has many decumbent stems

3. Can withstand poor drainage



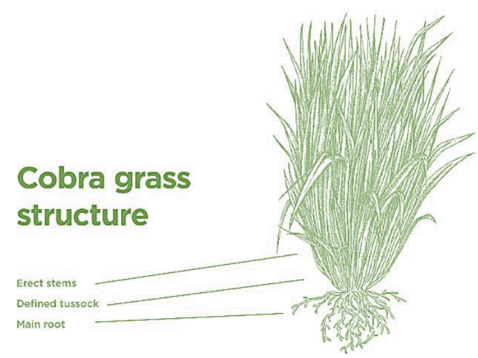
Brachiaria cv. Cobra

Characteristic	Rating
Palatability	High
Digestibility	High (69%)
Crude protein content	Up to 17% (depending on soil fertility)
Tolerance to water logging	Low
Tolerance to drought	Good
Tolerance to shade	Poor
Water requirement	Min. 800 mm/year
Planting density	8 -10 kg/ha, zero tillage
Planting depth	2 cm
Germination	7 – 21 days
Days to first cut	90 days
Time in rotation	30 – 45 days (wet season); 75 days (dry season)
Plant height	?
Production potential	More than 20 tons dry matter/ha/year
Soil fertility requirements	Medium to high
Adaptability to acidic soils	High
Resistance to spittlebug	High

Other characteristics

1. Has erect growth with well-defined tussocks making it ideal for cut and carry

2. Recovers quickly from cutting and grazing



ical Seeds, LLC.

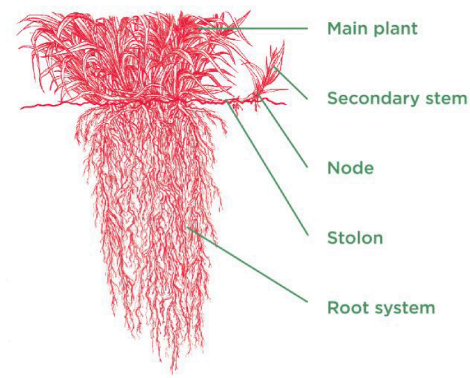
***Brachiaria* cv. Mulato II**

Characteristic	Rating
Palatability	High
Digestibility	High
Crude protein content	Up to 18% (depending on soil fertility)
Tolerance to water logging	Poor
Tolerance to drought	Good
Tolerance to shade	Poor
Water requirement	Min. 800 mm/year
Planting density	8 -10 kg/ha, zero tillage
Planting depth	2 cm
Germination	7 – 21 days
Days to first cut	70 - 80 days
Time in rotation	25 – 45 days (wet season); 60 - 70 days (dry season)
Plant height	80 – 100 cm
Production potential	On less fertile land (ph 4.7) 14 – 17 tons dry matter/ha/year. On highly fertile soils (ph. 6.3) up to 35 tons dry matter/ha/year
Soil fertility requirements	Medium to high
Adaptability to acidic soils	High
Resistance to spittlebug	High

Other characteristics

1. Recommended for regions acid soils of medium to low fertility

2. It can withstand prolonged periods of drought and high temperatures



Boma Rhodes attributes

Characteristic	Rating
Palatability	High but declines as the plant grows older especially during seeding
Crude protein content	8–50 % when flowering but declines as the plant grows older
Dry matter	86 %
Crude fibre	35 %
Lignin	5.6 %
Neutral Detergent Fibre (NDF)	75 %
Acid Detergent Fibre	41 %
Ash	10 %
Organic matter digestibility	63 %
Energy digestibility	59 %
Nitrogen digestibility	9 %

Ordinary (rice straws) hay

Characteristic	Rating
Palatability	High but declines as the plant grows older especially during seeding
Crude protein content	3–6 %
Dry matter	92–96 %
Crude fibre	35 %
Lignin	5.6 %
Neutral Detergent Fibre (NDF)	69 %
Acid Detergent Fibre (ADF)	42 %
Ash	18 %
Organic matter digestibility	50 %
Energy digestibility	47 %
Nitrogen digestibility	2 %

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