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RURAL FARMER'S PREFERENCE FOR SEED ATTRIBUTES AND SUPPORT SERVICE FROM GRAIN TRADERS INFLUENCE THE ADOPTION OF IMPROVED VARIETIES IN MUBI REGION, ADAMAWA STATE, NIGERIA

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ABSTRACT
This study examined the joint association of traders' support services and seed attribute preferences on the adoption of improved sorghum, beans, and groundnut seed varieties in Mubi region. The study involved 961 farmers from major production districts of beans, sorghum and groundnuts. 315 bean, 317 sorghum, and 329 groundnut farmers from five (5) local government area (4 districts per crop) in Adamawa State, Nigeria. Data collection was conducted using a household survey via Survey CTO, and data analysis was analyzed using descriptive statistics, independent sample T test and Chi-square test. Results show that 89.2% credit on improved seed such as sorghum and groundnuts significantly enhances adoption when paired with key traits such as high yield (P Value 0.003), grain price (P Value 0.000), grain size (P. Value 0.000), drought tolerance (P Value 0.000), and pest-disease resistance (P Value 0.001). Market-based supports like market guarantee (63.6%) and market linkage (74.5%) also demonstrate strong joint effects with traits like attractive price (0.996), grain color (0.838), and maturity time (0.789), particularly in common beans and groundnuts. These findings highlight the critical role of integrated traders' support and seed trait alignment in driving smallholder farmers' seed adoption decisions.

Keywords: Improved seed adoption, Traders' support service, Seed preference, Sorghum, Groundnuts, Beans, Mubi region

INTRODUCTION
Agriculture plays a pivotal role in Nigerian economy, engaging over 65% of the population and accounting for 26% of the country's Gross Domestic Product (GDP) (Rugeiyamu *et al.,* 2022). Smallholder farmers dominate the agricultural landscape, cultivating a diverse mix of food and cash crops that sustain food security and generate income. Beans, sorghum, and groundnuts are among the vital crops which serve as staple foods, key sources of protein, and important cash crops across many regions of Nigeria (Jomo *et al.,* 2025). These legumes and cereals contribute not only to income, nutrition and dietary diversity but also to soil fertility through nitrogen fixation, enhancing the sustainability of farming systems (Giller *et al.,* 2012). However, despite their critical importance, productivity levels for these crops remain relatively low due to a combination of agronomic, socio-economic, and institutional constraints. With limited adoption of improved seed varieties being a major bottleneck (Mabaya, 2016; Justus *et al.,* 2021).
Improved varieties offer a proven means to increase yields, improve resilience to biotic and abiotic stresses, and meet evolving market demands (McGuire & Sperling, 2016). These varieties often possess superior attributes such as drought tolerance, pest and disease resistance, shorter maturity periods, and grain quality attributes preferred by consumers and traders (Abebe *et al.,* 2015; ICRISAT, 2021). Such attributes are crucial in Nigeria agro-ecological zones that are increasingly vulnerable to climate variability and where farmers face mounting production risks (Change, 2001). Yet, despite the availability of improved seed varieties through both formal and informal seed systems, their uptake by smallholder farmers remains low and inconsistent across crops and regions. For instance, in Nigeria, only about 24% of cultivated area was planted with improved seed varieties (World Bank, 2022).
Understanding the drivers and barriers of improved varieties adoption requires a multifaceted approach. Traditionally, research and development efforts in Nigeria have emphasized public sector extension services and seed companies as the main vehicles for seed dissemination (Mulesa *et al.,* 2021). However, these actors have had limited reach and effectiveness in many rural areas, partly due to resource constraints and infrastructural challenges (URT, 2021). Recent shifts in agricultural value chains have highlighted the growing importance of private sector actors, notably grain traders, as intermediaries with the potential to influence farmers' behavior through market linkages and input support (Vecedom, 2022).
Grain traders play a crucial role in rural agricultural markets by linking farmers to urban and regional consumers. Apart from buying produce, traders are now offering services that help reduce the risks and costs of adopting new technologies (Getaw *et al.,* 2014). These services include providing market information, input credit like seeds and fertilizers, production loans, and market guarantees through forward contracts (World Bank, 2017). Involvement of traders in easing challenges such as limited financing and market uncertainty has been influencing the adoption of improved varieties (Jack, 2013).
Alongside traders' support mechanism, farmers' perceptions of seed attributes are central determinants of adoption decisions. Studies have shown that farmers weigh multiple seed characteristics, balancing agronomic performance with market preferences and household needs (Lutomia & Nchanji, 2022). Attributes such as drought and pest resistance, grain size and color, cooking time, taste, and compatibility with

local farming practices significantly influence farmers' willingness to adopt improved varieties (Abebe *et al.,* 2015). Moreover, when seed attributes align well with farmers' production realities, market opportunities and sensory preference, the adoption likelihood increases substantially (Justus *et al.,* 2021).

Despite the acknowledged importance of both traders' support and preference for seed attributes, most existing research have examined these factors in isolation (Martey *et al.,* 2020; Mulesa *et al.,* 2021). Fisher *et al.* (2015) emphasized that farmers' adoption decisions are shaped not only by varietal traits such as yield potential and drought tolerance but also by the market incentives and institutional linkages available to them. Arouna *et al.* (2017) found that when quality seed is bundled with services such as credit, input supply, and output market access, adoption rates increase substantially. Together, these studies highlight the importance of integrating both supply- and demand-side factors in explaining varietal turnover and sustained seed use among smallholder farmers. Moreover, the heterogeneity in seed systems, market dynamics, and farmer preferences in sorghum, beans and groundnuts calls for a nuanced analysis that can inform tailored interventions (Langyintuo *et al.,* 2010).

This study addresses these knowledge gaps by exploring the association between grain traders' support services and farmers' preference on farmers' adoption of improved bean, sorghum, and groundnut varieties in Mubi region of Adamawa State, Nigeria. Specifically, it investigates how traders' provision of market information, credit facilities, input credit, and market guarantee influence adoption decisions, alongside farmers' valuation of seed traits such as yield, resilience, sensory attributes and marketability. By providing empirical evidence on the combined effect of institutional support and seed preference, this research aims to inform the design of more effective, market-oriented seed system interventions that can accelerate adoption, enhance agricultural productivity, and improve rural livelihoods.

MATERIALS AND METHODS

Mubi region is made up of five out of the 21 local government areas namely Madagali, Maiha, Michika, Mubi North and Mubi South. The five local governments are further divided into 25 districts. The district is headed by a traditional leader called the district head (Mshelia, 2004). The region is culturally rich and is blessed with scenic horizons and a pleasant weather.

The region was delineated on the basis of socio-political factors to form Adamawa north senatorial district as defined by INEC (1996). It lies between latitude 9° 30' and 11° north of the equator and longitude 13° and 13° 45' east of the Greenwich meridian. Mubi region is bounded in the north by Borno state, in the west by Hong and Song local government areas and in the south and east by the Republic of Cameroon (Figure 1), (Mshelia, 2004). It has a land area of 4728.77 km² and a population of 968,969 persons in 2011(1991 Census Projected Figure).

The study area has a tropical climate marked by two seasons- the dry and wet season. The wet season commences in late March/April and lasts till October every year. While the dry season starts in November and lasts till February, resulting in a slightly cool period, there is a gradual increase in temperature from January to April with seasonal maximum occurring in April. The average mean annual rainfall ranges from 700mm in the north-west part to 1600mm in the southern part. Mubi region being situated on hill ranges has a relatively friendly weather that is cool most of the year, creating a heavy contrast from what is obtained in Yola, the state capital, thus, providing a good scene for holiday and resorts (Adebayo, 1997).

Landform types in Mubi region can be grouped into valleys and troughs, upland plains, lowlands and hills/mountain ranges. The lowland areas constitute about 32.58%, while mountain ranges which are the most striking landform features constitute about 26.56% and the upland plains 40.85%. Elevation (altitude) is a local factor which affects temperature in the tropics. The effect of elevation is noted in Mubi region, being situated on hill ranges. These create appealing picturesque, enhancing scenic beauty as well as a soothing ambiance.

Mubi region is the second most populated region in Adamawa state (Nwagboso and Uyanga 1999) with a projected population, as at 2011, of 968,969 persons with density of 205 persons per square kilometer. The total population of Adamawa State, as recorded in the 1991 population census was 2,102,053 with 50.01% being female. The census revealed that the literacy level to be 44.6% and about 41.4% being gainfully employed. With 68 languages and 70 ethnic groups, Adamawa is noted as being linguistically heterogeneous in nature epitomizing a true microcosm of the general linguistic diversity of Nigeria and indeed Africa.

The urban areas in Mubi region have land uses such as transportation, residential, commercial, industrial, institutional and recreational exist. While in the rural areas residential, fishing, livestock rearing activities and farming are predominant. These avail in large quantity, varieties of fresh farm produce for the exotic cuisines the region is known for. Also, traditional music and folklores are enjoyed most evenings and during ceremonies in rural and semi urban areas of the region.

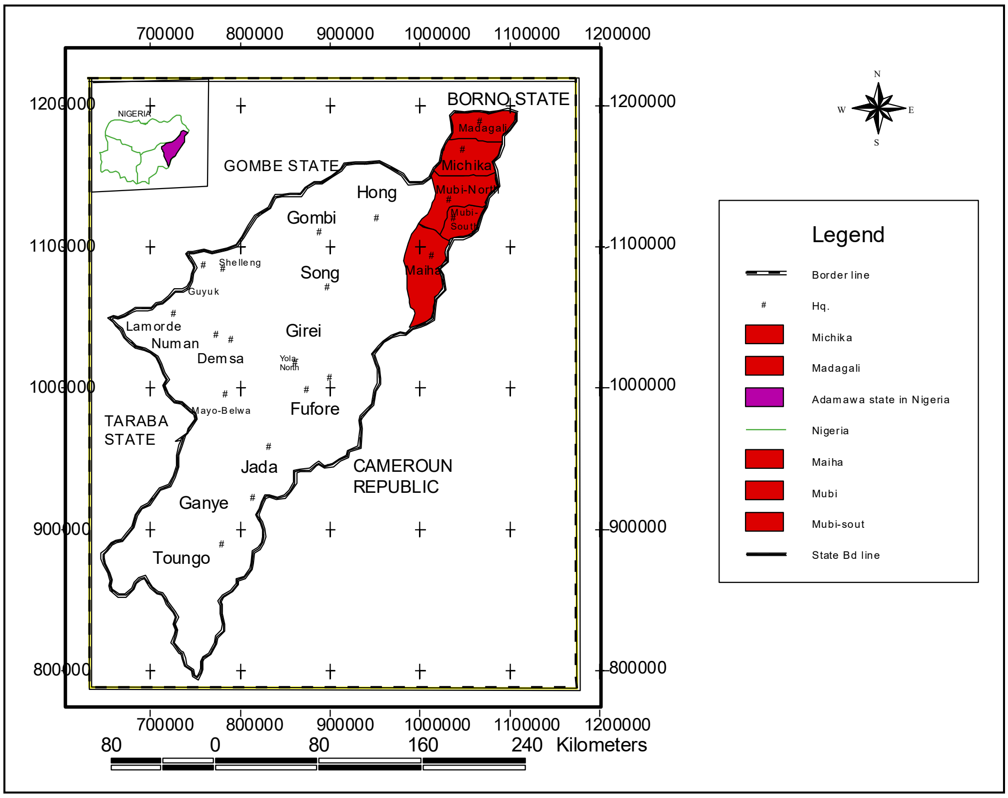

Figure 1: Adamawa State showing Mubi Region
Source: G.I.S LAB ADSU modified by Author in Adebayo (2004)

Sample Size Determination

The sample size was calculated using Cochran's (1963) formula, which balances efficiency and reliability by avoiding overly large samples that waste resources and overly small ones that compromise result validity.

Where for each of the crop, the sample size (n) was determined using Cochran (1963) formula:

$$n = \frac{Z^2pq}{e^2} \qquad (1)$$

Where Z is the Z-Score at 95% level of confidence (which is 1.96);

P= estimated variance in the population of interest. In this case is 30% representing the current adoption rate of improved seed varieties (Woldeyohannes *et al.,* 2022).

q= 1-p; and

e= margin of error (5%).

The intended sample included 323 farmers per crop, totaling 969 households. However, due to geographic barriers, social events, and time limitations, six sorghum and eight groundnut farmers could not be reached, reducing the final sample to 961. Some responses were also excluded due to non-participation or unusable data (Groves *et al.,* 2009). Despite this, the final sample sizes per crop remained sufficient for statistical analysis, meeting Central Limit Theorem (CLT) criteria for large-sample inference (Kwak & Kim, 2017).

Sampling Procedure

A multistage sampling approach was used to select individual households, including both adopters and non-adopters of improved seed varieties in the entire crops. This method was particularly appropriate for distinguishing between the two groups. It was chosen because it integrates both probability and non-probability sampling techniques, offering flexibility in sample selection.

Initially, purposive sampling was employed to identify four key production lga for each crop; sorghum, common beans, and groundnuts. These LGA were selected based on their historical and current significance in crop production, agro-ecological suitability, and accessibility of both adopters and non-adopters of improved seed varieties. Selection was informed by secondary production statistics from the Ministry of Agriculture (URT, 2021). Within each LGA, two major crop-producing wards were identified in collaboration with local government authorities and extension experts, ensuring that the sampling frame included areas with known variation in adoption behavior. These wards were believed to have a mix of households using traditional and improved seeds, thus increasing the likelihood of capturing heterogeneity in adoption status.

The final selection of participating households was conducted using simple random sampling at the ward level for each specific crop, ensuring that every household involved in production had an equal chance of being included. This two-stage sampling approach combining purposive and random sampling ensured both relevance and representativeness, yielding 317 households for sorghum, 315 for common beans, and 329 for groundnuts. The distribution of selected respondents across the survey is shown in Table 1.

Table 1: Sample Distribution in the Study Area (n=961)

Crop	District	Ward	Respondents	Adopters	Non-Adopters	Adopters (%)	Non-Adopters (%)
	Maiha	1. Mayoguli	30	6	24	20.0	80.0
		2. Pakka	53	6	47	11.3	88.7
	Madagali	3. Madagali	35	27	8	77.1	22.9
		4. Gulak	43	22	21	51.2	48.8
	Mubi	5. Sabon Layi	46	8	38	17.4	82.6
		6. Yelwa	29	4	25	13.8	86.2
	Michika	7. Bazza	34	19	15	55.9	44.1
		8. Michika	47	18	29	38.8	61.7
Total			**317**	**110**	**207**	**34.7**	**65.3**
Beans (n=315)	Maiha	1. Mayoguli	26	9	17	34.6	65.4
		2. Pakka	52	16	36	30.8	69.2
	Madagali	3. Madagali	34	21	13	61.8	38.2
		4. Gulak	44	21	23	47.7	52.3
	Mubi	5. Sabon Layi	43	36	7	83.7	16.3
		6. Yelwa	38	36	2	94.7	5.3
	Michika	7. Bazza	42	24	18	57.1	42.9
		8. Michika	36	22	14	61.1	38.9
Total			**315**	**185**	**130**	**58.7**	**41.3**
Groundnuts (n=329)	Maiha	1. Mayoguli	51	5	46	9.8	90.2
		2. Pakka	27	6	21	22.2	77.8
	Madagali	3. Madagali	41	4	37	9.8	90.2
		4. Gulak	40	9	31	22.5	77.5
	Mubi	5. Sabon Layi	41	5	36	12.2	87.8
		6. Yelwa	45	22	23	48.9	51.1
	Michika	7. Bazza	42	30	12	71.4	28.6
		8. Michika	42	24	18	57.1	42.9
Total			**329**	**105**	**224**	**31.9**	**68.1**

Design Limitation

However, the study design had a limitation in that it did not employ a stratified sampling approach that would have explicitly separated adopters and non-adopters within each ward before random selection. A stratified random sample would have ensured more balanced representation and improved comparability between the two groups (Neyman, 1992).

Data Collection

The study used primary data collected from 961 farmers involved in the three target crops, as detailed in Table 1 using structured face to face interviews in household survey which were conducted via Survey CTO platform. Additionally, the data collection tool was pretested in Mubi to enhance its quality and reliability. Various information were collected during survey include household socio demographic characteristics, type of variety grown by a farmer for each crop either improved or local variety to capture adoption status of the farmers and grain traders' support services received by the farmers, and the seed attribute preference using forced choice rating options on each seed attribute for understanding whether the attribute is important or not to avoid neutral option.

Data Synthesis and Analysis

After gathering qualitative and quantitative data on various factors described by the theory of diffusion, the descriptive statistics, forced choice rating scale, independent sample T test and Chi square test of independence were used to analyze data. Descriptive statistics encompassed the computation frequency, and percentages on descriptive results and farmers' access on traders' support services. The social, economic, and demographic characteristics studied included gender, farmer cooperative membership, non-farm income, crop insurance, access of formal credit.

Forced choice rating scale was used to analyze the farmers' preference on seed attributes to understand the attributes farmers prefer highly in order for them to use a certain variety based on their socio-economic context. This approach is compelling farmers to provide a definitive stance without the option of neutrality, consistent with best practices for reducing central tendency bias in attitudinal surveys (Zhang *et al.,* 2024; Brown & Maydeu-Olivares, 2011).

In addition, an Independent Samples t-test was conducted to determine whether there were statistically significant differences in seed attribute preferences between adopters and non-adopters of improved seed varieties. This test compares the mean scores of two independent groups here, Group 1 (non-adopters) and Group 2 (adopters) to assess whether the average importance attached to specific seed attributes differs significantly between them. The preference scores, initially measured on a four-point ordinal Likert scale (1 = *Not important at all*, 2 = *Not important*, 3 = *Important*, and 4 = *Very important*), were treated as continuous variables for analysis, a practice commonly accepted in social science and behavioral research when Likert scales have four or more categories and approximate interval properties (Carifio & Perla, 2008; Norman, 2010). Also, Kassie et al. (2013) applied a similar approach to examine differences in farmers' preferences for maize traits in Ethiopia.

Furthermore, the Chi-square test of independence was employed to examine the association between farmers' seed attribute preferences and their adoption of improved seed varieties, specifically among those receiving various forms of grain traders' support services. This approach aimed to evaluate how the integration of trader support mechanisms and farmers' seed attribute preferences jointly influence adoption decisions across sorghum, beans, and groundnuts. The preference data were originally collected using a four-point forced-choice Likert scale (1 = *Not important at all*, 2 = *Not important*, 3 = *Important*, and 4 = *Very important*). For analytical clarity and to meet the assumptions of the Chi-square test, the scale was collapsed into two categories: Category 1 (Important attribute) combining *important* and *very important*, and Category 2 (Not important attribute) combining *not important* and *not important at all*. The resulting binary preference categories were then cross-tabulated with the adoption variable (coded as *1 = adopter* and *0 = non-adopter*) to test for statistical association. Mignouna *et al.* (2011) used Chi-square tests to examine associations between farmers' perceptions and adoption of improved cowpea varieties, while Abebe *et al.* (2015) employed the same method to assess the link between varietal traits and potato technology adoption. Therefore, the use of Chi-square analysis in this study is both statistically justified and consistent with standard practices in socio-economic and adoption studies within agricultural research.

RESULTS AND DISCUSSION

Socio-economic Characteristics of Adopters and Non-adopters of Improved Seed Varieties

The socio-economic characteristics presented in Table 2 illustrate that adopters and non-adopters of improved seed varieties across sorghum, beans, and groundnuts generally share comparable profiles, suggesting that both groups are reasonably representative of the broader smallholder population. The average age of farmers range between 44 and 49 years across all crops, indicating that most farmers are middle-aged adults actively engaged in farming as their primary livelihood. Also, household sizes are relatively large (6-8 members on average), consistent with rural household structures in Mubi region, which often rely on family labor for crop production. The comparability in these demographic attributes across adopters and non-adopters helps ensure that any observed differences in seed preference or adoption behavior are less likely to stem from basic demographic imbalances.

Regarding education, farm size, and farming experience, the two groups appear broadly similar across crops, implying that human capital and resource endowment differences are minimal. Average years of schooling (6-8 years) reflect completion of primary education, suggesting that both adopters and non-adopters possess sufficient literacy to understand extension messages and seed quality information. This comparability is crucial because education has been shown to influence adoption behavior through improved information access and decision-making capacity (Asfaw *et al.,* 2012; Wainaina *et al.,* 2016). Moreover, the average landholding sizes are small (below 2 ha), typical of Nigerian smallholders (Anderson *et al.,* 2016), and do not differ significantly between groups. The resemblance in resource endowment and farming experience suggests that both adopters and non-adopters operate under similar production constraints, supporting the representativeness and fairness of subsequent analyses.

Institutional and informational factors, however, show some observable differences that may influence adoption decisions. A higher proportion of adopters across all crops reported access to formal credit, cooperative membership, and extension services, as well as greater awareness of improved seed varieties. These patterns are consistent with findings by Mignouna *et al.* (2011) and Adegbola and Gardebroek (2007), who reported that institutional linkages and access to information facilitate technology uptake by reducing uncertainty and transaction costs. Nonetheless, these variations do not appear large enough to suggest systematic bias between adopters and non-adopters. Instead, they highlight the importance of supportive services in enhancing adoption rather than reflecting fundamental socio-economic disparities. Overall, the two groups can be considered comparable and representative, which strengthens the validity of subsequent inferential analyses on seed preference and adoption dynamics.

Access to Trader Support Services Based on Improved Seed Adoption per Crop

The distribution of traders' Support Services varies across crops among adopters and non-adopters. By definition Traders' Support Services refer to the various types of assistance and facilitative roles that grain traders provide to farmers beyond simply purchasing produce (Sitko & Jayne, 2014). Support services are normally provided during production and marketing of produce. These services are important because they influence farmers to adopt improved varieties by reducing market, financial, and information-related risks (Spielman *et al.,* 2011). The results presented in Table 3 reveals a substantial disparity in access to trader-provided services between adopters and non-adopters of improved seed varieties across sorghum, beans, and groundnuts. For sorghum, adopters reported much greater access to all trader services than non-adopters. Notably, 86.4% of adopters accessed market information compared to 41.5% of non-adopters. Access to market linkage (74.5%) and market guarantees (63.6%) was also markedly higher among adopters, suggesting that traders play a vital role in connecting sorghum farmers to output markets and reducing market uncertainty. Moreover, 53.6% of adopters received improved seed credit, compared to only 21.3% of non-adopters, implying that financial constraints are a key barrier to adoption (Feder *et al.,* 1985).

In the case of common beans, adoption appears to be highly associated with market information (89.2%), seed credit (55.7%), and input bundling credit (46.5%). Compared to non-adopters, who accessed these services at lower rates (53.1%, 33.8%, and 30.8%, respectively), adopters benefit more from integrated support services. Input bundling credit, in particular, seems to encourage adoption by providing ready-made packages that reduce search and transaction costs (Spielman *& Smale,* 2017). Moreover, market guarantees (50.8%) and linkages (57.3%) also play important roles in influencing adoption, especially in semi-commercializing bean value chains where assured markets can justify farmers' shift to improved seeds (Barrett*,* 2008).

Among the three crops, groundnut adopters reported the largest gap in access to trader services compared to non-adopters. For instance, 62.9% of adopters had access to improved seed credit, compared to just 20.5% of non-adopters a gap of over 40 percentage points. Similarly, access to market linkage (67.6%), market guarantee (59.0%), and input bundling (49.5%) was significantly higher among adopters. These results emphasize the central role of traders in overcoming adoption barriers in groundnut production, particularly in contexts where certified seed systems are weak or informal (Abate *et al.,* 2015). Traders in groundnuts appear to provide bundled services and market connections that lower risk and improve seed access, facilitating a more enabling environment for adoption (Asfaw *et al.,* 2012).

Table 2: Socio-economic Characteristics of Adopters and Non-adopters of Improved Seed Varieties

Socio-economic characteristic	Category / Unit	Sorghum			Beans			Groundnuts		
		Adopters (n=110)	Non-adopters (n=207)	p-value	Adopters (n=185)	Non-adopters (n=130)	p-value	Adopters (n=105)	Non-adopters (n=224)	p-value
Age	Mean years	48.4	47.3	0.458	46.2	44.8	0.329	48.8	44.8	0.007
Household size	Mean number of members	7	8	0.001	6	6	0.085	6	7	0.001
Farming experience	Mean (years)	19.5	16.7	0.062	15.8	13.6	0.115	18.3	13.9	0.003
Education level	Mean years of schooling	6.5	6.8	0.422	7.9	7.6	0.338	6.8	7.1	0.256
Farm size	Mean (ha)	1.4	1.4	0.981	0.97	0.83	0.158	1.6	1.3	0.345
Farmer cooperative members	(% members)	41.8	25.1	0.002	38.9	31.5	0.179	49.5	37.5	0.039
Non-farm income	(% with	45.5	36.2	0.110	47.6	46.2	0.805	41.0	43.8	0.633
Access to formal credit	(% with access)	17.3	7.7	0.010	23.8	13.1	0.018	21.9	14.3	0.084
Extension service	(% with access)	58.2	56.5	0.776	57.8	49.2	0.131	58.1	43.8	0.015
Awareness on improved seed	(% awareness)	83.6	52.7	0.000	87.0	51.5	0.000	88.6	18.8	0.000
Gender of household head	(% Male)	70.0	72.9	0.578	69.2	63.8	0.321	61.0	47.8	0.026

Table 3: Access to Trader Services by Adoption Status and Crop

Crop	Adoption Status	N	% Market information	% Non- seed single input credit	% Improved seed credit	% Input bundling credit	% Production loan	% Market linkage	% Market guarantee
Sorghum	Adopters	110	86.4	39.1	53.6	33.6	37.3	74.5	63.6
	Non-Adopters	207	41.5	26.1	21.3	28.5	29.0	25.1	20.8
Beans	Adopters	185	89.2	28.6	55.7	46.5	42.7	57.3	50.8
	Non-Adopters	130	53.1	34.5	33.8	30.8	31.5	34.6	32.3
Groundnuts	Adopters	105	72.4	38.1	62.9	49.5	39.0	67.6	59.0
	Non-Adopters	224	25.4	32.6	20.5	25.9	26.8	20.5	20.1
Pooled	Adopters	400	84.0	34.0	57.0	43.8	40.2	64.8	56.5
	Non-Adopters	561	37.8	30.7	23.0	28.0	28.7	25.5	23.2

Farmer Preference Attributes for Adopting Improved Seed Varieties

Table 4 highlights variations in farmers' preferences for seed attributes across sorghum, beans, and groundnuts, using Forced-Choice (FC) scale ratings (1 = *Not important at all*, 2 = *Not important*, 3 = *Important*, and 4 = *Very important*). Higher mean scores indicate greater importance. Attributes with mean scores above the crop-specific weighted average are classified as highly preferred, while those below are less preferred. This approach highlights the key seed characteristics influencing variety adoption in each crop system.

Results show that sorghum farmers expressed strong preference for yield (3.89), marketability (3.70), drought tolerance (3.60), and grain color (3.57), echoing findings from Smale *et al.* (2014) and Zimba *et al.* (2025) that highlight the importance of drought-resilient, high-yielding and marketable sorghum varieties in semi-arid zones. Maturity (3.67) and pest resistance (3.49) are also prioritized, indicating a preference for early-maturing and robust varieties in areas with short rainfall seasons and pest pressure. Conversely, attributes such as heat tolerance (2.05), cooking time (2.08), and nutritive value (2.21) scored poorly, likely due to the perceived difficulty in observing or measuring these attributes directly at the farm level.

In the case of beans, the most preferred traits were marketability (3.96), yield (3.93), pests and disease tolerance (3.73), and grain color (3.45). This shows a similar trend to groundnuts in which market-driven and productivity traits dominate. Farmers also valued maturity (3.55) and grain price (3.55), reinforcing the economic motive in seed choice. Attributes like cooking time (3.07) and taste (3.23), while somewhat valued, were less prioritized, consistent with studies in East Africa where grain characteristics affecting income take precedence over culinary traits (Katungi *et al.,* 2011). Furthermore, seed price (3.21) and grain appearance (3.19) were marginally less preferred, which could suggest that while input affordability matters, farmers may be willing to pay more for quality seed with desirable traits.

Moreover, groundnuts farmers prioritize attributes related to productivity and market performance. Yield (3.90), marketability (3.86), pests and disease tolerance (3.57), grain color (3.52), and grain size (3.49) were among the most highly preferred attributes, suggesting a strong orientation toward traits that improve output and enhance returns in the market. This aligns with earlier findings by Asrat *et al.* (2010), who noted that smallholder farmers prioritize visible and market-responsive traits when selecting varieties. Attributes such as maturity (3.51) and drought tolerance (3.41) were also ranked highly, reflecting farmers' awareness of the need for climate-resilient varieties under rain-fed conditions a concern well-documented in dryland farming systems (Fisher *et al.,* 2015). However, traits such as cooking time (2.16) and taste (2.94) received lower preference, perhaps due to the commercialization of groundnut farming where market traits outweigh household consumption concerns. Interestingly, heat tolerance (2.37) and nutritive value (2.53) were rated as less important despite their agronomic and health implications, suggesting gaps in awareness or short-term priority bias among farmers.

A cross-crop comparison show shared preferences like yield, drought tolerance, and marketability, but some traits are crop-specific. Grain appearance is more valued in groundnuts, while cooking traits (taste, time) are less consistently preferred. These differences highlight the need for crop-specific breeding and seed delivery strategies (Wale & Yalew, 2007). Additionally, the low preference for heat tolerance and nutritive value, despite increasing climate variability and malnutrition concerns, suggests a knowledge gap that extension services could address to shift farmer priorities toward longer-term resilience and health outcome.

Table 4: Farmers' Preferred Seed Attributes in Sorghum, Beans, and Groundnuts

Attribute	Sorghum			Beans			Groundnuts		
	Mean	Std	Preference	Mean	Std	Preference	Mean	Std	Preference
Yield	3.89	0.492	High	3.93	0.363	High	3.90	0.445	High
Maturity	3.67	0.708	High	3.55	0.761	High	3.51	0.789	High
Withstand excess rainfall	2.83	1.009	Low	3.38	0.775	High	3.08	0.892	Low
Plant appearance	2.95	1.040	Low	3.01	0.959	Low	3.10	0.948	Low
Drought tolerance	3.60	0.812	High	3.36	0.875	High	3.41	0.869	High
Pests & disease tolerance	3.49	0.837	High	3.73	0.604	High	3.57	0.790	High
Heat tolerance	2.05	1.053	Low	2.43	1.051	Low	2.37	1.130	Low
Grain size	3.21	1.037	High	3.36	0.826	High	3.49	0.830	High
Grain appearance	3.07	0.961	Low	3.19	0.868	Low	3.30	0.879	High
Grain color	3.57	0.851	High	3.45	0.867	High	3.52	0.838	High
Taste	3.17	1.013	High	3.23	0.917	Low	2.94	1.134	Low
Cooking time	2.08	1.150	Low	3.07	1.064	Low	2.16	1.199	Low
Grain price	3.36	1.005	High	3.55	0.810	High	3.47	0.924	High
Seed price	3.06	1.051	Low	3.21	0.941	Low	3.20	0.996	High
Nutritive value	2.21	1.141	Low	2.48	1.118	Low	2.53	1.210	Low
Pod/Panicle size	2.91	1.188	Low	2.90	1.083	Low	3.19	1.043	High
Shelling/Threshing ease	2.92	1.043	Low	2.92	1.059	Low	3.19	0.993	High
Oil content	—			—			2.94	1.125	Low
Marketability	3.70	0.805	High	3.96	0.290	High	3.86	0.567	High
Calculated Weighted Average	3.09			3.26			3.14		

Note: Attribute scoring above calculated weighted average values are classified as highly preferred, while those scoring below are considered less preferred.

Seed Preference between Adopters and Non-adopters in Sorghum, Beans and Groundnuts

The results presented in Table 5 show the differences in mean seed attribute preferences between adopters and non-adopters of improved seed varieties, as analyzed using the Independent Samples t-test. In this analysis, non-adopters were coded as Group 1 and adopters as Group 2. The mean difference for each seed attribute was obtained by subtracting the mean score of Group 2 (adopters) from that of Group 1 (non-adopters). Thus, a negative mean difference indicates that adopters assigned a higher preference score to a given attribute than non-adopters, implying that adopters placed greater importance on that seed trait than non-adopters. Furthermore, the p-value associated with each t-test determines whether the observed difference in mean preference between the two groups is statistically significant. A p-value less than 0.05 indicate that the difference in mean preference is statistically significant difference between adopters and non-adopters regarding the importance placed on that seed attribute (Field, 2024; Pallant, 2020).

The Independent Samples t-test indicates notable and statistically significant differences in some seed attribute preferences between adopters and non-adopters across sorghum, beans, and groundnuts. In sorghum and groundnuts, adopters place relatively higher importance on climate-resilient and post-harvest traits (e.g., drought and excess-rainfall tolerance, maturity, grain/seed price, grain/seed size and appearance, nutritive value, and threshing/shelling ease), with many p-values < 0.05. By contrast, beans show fewer significant gaps between groups, with only a small subset of attributes (drought tolerance, rainfall tolerance, and grain price) reaching significance. These results suggest that adopters are more selective and prioritize a broader set of agronomic and market traits than non-adopters, while beans often a household staple exhibit more uniform preferences across farmer groups (Kassie *et al.,* 2017; Ochieng *et al.,* 2022).

The pattern that adopters emphasize tolerance to abiotic stress and post-harvest qualities is consistent with the literature showing farmers' prioritization of resilience and processing/market attributes in semi-arid environments. Several studies report that drought tolerance, early maturity, and tolerance to erratic rainfall are top priorities for sorghum and other dryland crops because they directly reduce production risk under variable climate conditions (Asfaw *et al.,* 2012; Ochieng *et al.,* 2019). Likewise, grain size, appearance, and ease of processing are repeatedly identified as attribute that increase market value and farmer willingness to adopt improved varieties (Abate *et al.,* 2015; Rohrbach *et al.,* 2002). These findings align with empirical work on sorghum trait preferences and breeding priorities in Tanzania (Kassie *et al.,* 2020).

The stronger preference gaps observed in sorghum and groundnuts versus beans can be explained by differences in crop uses and market orientation. Groundnuts and sorghum frequently serve both household consumption and commercial markets, so farmers who adopt improved varieties tend to place greater weight on traits that enhance marketability and income (price, size, nutritive value) as well as resilience. Reviews and recent analyses of legume and groundnut seed systems likewise emphasize the importance of aligning breeding and seed delivery with farmers' market-oriented trait demands to raise adoption rates (Simtowe *et al.,* 2019; Ochieng *et al.,* 2022). In contrast, beans are often grown primarily for home consumption and food security, which can homogenize trait priorities across adopters and non-adopters and reduce observed mean differences (Katungi *et al.,* 2011).

Table 5: Independent Samples T-test Results on the Seed Preference between Non adopters and Adopters

Attribute	Sorghum			Beans			Groundnuts		
	Mean Difference	Std. Error Difference	P-value	Mean Difference	Std. Error Difference	P-value	Mean Difference	Std. Error Difference	P-value
Yield	0.100	0.66	0.132	-0.020	0.042	0.635	-0.115	0.038	0.003
Maturity	-0.081	0.084	0.336	-0.162	0.087	0.062	-0.290	0.083	0.001
Withstand excess rainfall	-0.461	0.116	0.000	-0.274	0.090	0.003	-0.420	0.103	0.000
Plant appearance	-0.458	0.120	0.000	-0.095	0.106	0.371	-0.366	0.110	0.001
Drought tolerance	-0.154	0.092	0.096	-0.199	0.100	0.046	-0.395	0.092	0.000
Pests & disease tolerance	-0.175	0.098	0.076	-0.125	0.070	0.078	-0.280	0.081	0.001
Heat tolerance	-0.457	0.130	0.001	-0.083	0.116	0.478	-0.290	0.139	0.039
Grain size	-0.340	0.116	0.004	-0.100	0.095	0.291	-0.368	0.085	0.000
Grain appearance	-0.178	0.114	0.120	-0.049	0.096	0.610	-0.379	0.093	0.000
Grain color	-0.047	0.101	0.639	0.037	0.095	0.699	-0.304	0.089	0.001
Taste	-0.454	0.111	0.000	-0.185	0.105	0.078	-0.560	0.131	0.000
Cooking time	-0.376	0.138	0.007	-0.087	0.120	0.467	-0.397	0.150	0.009
Grain price	-0.047	0.118	0.688	-0.233	0.093	0.012	-0.427	0.092	0.000
Seed price	-0.331	0.123	0.007	-0.173	0.104	0.097	-0.694	0.094	0.000
Nutritive value	-0.757	0.132	0.000	-0.122	0.124	0.325	-0.701	0.138	0.000
Pod/Panicle size	-0.419	0.131	0.002	-0.042	0.124	0.735	-0.208	0.123	0.091
Shelling/Threshing ease	-0.404	0.121	0.001	-0.239	0.121	0.048	-0.400	0.116	0.001
Oil content	-			-			-0.537	0.124	0.000
Marketability	0.093	0.101	0.360	0.018	0.033	0.591	-0.043	0.065	0.511

Integration of Traders' Support Services and Seed Attributes on Farmers' Adoption of Improved Varieties

The Chi-square analysis revealed that farmers' seed attribute preferences are significantly associated with adoption of improved varieties within groups receiving trader support services, although patterns varied across crops and service types. Among sorghum farmers, significant associations were observed between adoption and key traits such as grain size ($p = 0.013$) and drought tolerance ($p = 0.047$) among those receiving market information and production loans, respectively. Similarly, sorghum farmers with access to market linkage services exhibited strong preference-adoption relationships for grain size ($p = 0.000$) and yield ($p = 0.006$). These results indicate that trader-provided information and market connectivity enhance farmers' valuation of market-driven traits like grain size and yield, which directly influence profitability and market acceptance. This finding is consistent with Ochieng et al. (2022) and Kassie *et al.* (2017), who reported that access to market information strengthens farmers' awareness of high-performing varieties and promotes adoption in semi-arid cereals like sorghum.

For beans, associations were weaker overall, though several traits showed moderate significance within specific service contexts. Farmers who accessed market information and production loans displayed significant preference-adoption relationships for drought tolerance (p = 0.043) and maturity (p = 0.017), respectively. Likewise, access to market linkage services was marginally associated with drought tolerance (p = 0.094) and grain appearance (p = 0.062). These results suggest that while beans remain primarily a subsistence crop, exposure to trader services encourages farmers to value resilience and quality attributes that enhance both consumption and sale potential. Similar trends were reported by Katungi *et al.* (2011) and Asfaw *et al.* (2012), who found that bean adopters in Eastern Africa valued short maturity and drought tolerance as coping strategies against climate variability, while market access further motivated the selection of high-quality bean types for trade.

In groundnuts, the associations were the strongest and most consistent across nearly all trader services, particularly for yield, maturity, grain price, and pest and disease resistance. For instance, significant associations were found for yield (p = 0.035) and grain price (p = 0.002) under improved seed credit, maturity (p = 0.028) and grain price (p = 0.043) under market information, and pest and disease resistance (p = 0.025) under improved seed credit. Farmers receiving market linkage and production loans also displayed significant alignment between adoption and market-oriented traits such as grain size (p = 0.006) and grain price (p = 0.024). These results imply that financial and informational services from traders not only facilitate adoption but also shape farmers' valuation of quality traits with higher market premiums. This aligns with evidence from Simtowe *et al.* (2019) and Abate *et al.* (2015), who observed that access to seed credit and market guarantees substantially increased the adoption of improved groundnut varieties with superior market and processing attributes in Malawi.

Table 6: Chi Square Results on Association between Seed Attribute Preferences and Adoption of Improved Seed Varieties among Farmers Receiving Trader Support Services

Trader support received	Seed Attribute	Sorghum		Beans		Groundnuts	
		χ^2 Value	p-value	χ^2 Value	p-value	χ^2 Value	p-value
Market information	Yield	2.368	0.099*	0.039	0.742	4.092	0.043**
	Maturity	1.123	0.289	0.186	0.666	4.807	0.028**
	Drought	0.223	0.637	4.095	0.043**	2.053	0.152
	Pest & disease resistance	0.121	0.992	0.533	0.465	0.616	0.433
	Grain size	6.169	0.013**	0.132	0.716	1.304	0.253
	Grain colour	0.823	0.364	0.157	0.692	2.053	0.152
	Grain price	0.377	0.539	4.126	0.042**	14.801	0.000***
Non Seed Single input credit	Yield	2.718	0.098*	0.858	0.354	1.689	0.194
	Maturity	0.135	0.714	3.149	0.076*	1.455	0.228
	Drought	0.085	0.771	0.004	0.950	3.688	0.055*
	Pest & disease resistance	0.020	0.887	0.074	0.785	0.972	0.324
	Grain size	1.358	0.244	0.336	0.562	1.455	0.228
	Grain colour	0.209	0.647	2.257	0.095*	2.062	0.151
	Grain price	0.024	0.878	0.829	0.363	4.931	0.026**
Improved seed credit	Yield	3.104	0.078*	1.308	0.053*	4.423	0.035**
	Maturity	1.693	0.193	0.438	0.508	6.392	0.011**
	Drought	0.355	0.551	2.843	0.092*	10.844	0.001***
	Pest & disease resistance	0.753	0.386	0.006	0.936	5.050	0.025**
	Grain size	1.530	0.216	0.581	0.446	1.655	0.198
	Grain colour	0.753	0.386	0.044	0.834	2.564	0.109
	Grain price	1.641	0.200	5.361	0.021**	9.918	0.002***
Input bundling credit	Yield	0.035	0.851	0.945	0.331	2.765	0.096*
	Maturity	3.316	0.069*	0.203	0.653	1.717	0.190
	Drought	1.214	2.271	0.807	0.369	3.463	0.063*
	Pest & disease resistance	0.057	0.812	1.314	0.252	0.764	0.382
	Grain size	0.029	0.865	1.300	0.254	1.961	0.161
	Grain colour	0.251	0.617	0.029	0.864	5.062	0.024**
	Grain price	2.889	0.089*	9.400	0.002***	3.282	0.070*
Production loan	Yield	0.068	0.795	1.056	0.304	0.690	0.406
	Maturity	0.016	0.899	5.662	0.017**	5.140	0.023**
	Drought	3.932	0.047**	0.363	0.547	1.383	0.240
	Pest & disease resistance	0.908	0.341	0.461	0.497	2.844	0.092*
	Grain size	2.515	0.113	0.017	0.897	1.952	0.162
	Grain colour	0.688	0.407	0.007	0.936	0.908	0.341
	Grain price	0.003	0.960	0.532	0.466	5.080	0.024**
Market linkage	Yield	2.615	0.006***	0.860	0.354	4.752	0.029**
	Maturity	0.045	0.831	1.185	0.276	1.935	0.164
	Drought	1.371	0.242	2.801	0.094*	4.315	0.038**
	Pest & disease resistance	0.440	0.507	0.239	0.625	8.669	0.003***
	Grain size	12.870	0.000***	1.045	0.307	7.586	0.006***
	Grain colour	0.046	0.830	0.795	0.373	2.118	0.146

Trader support received	Seed Attribute	Sorghum		Beans		Groundnuts	
		χ² Value	p-value	χ² Value	p-value	χ² Value	p-value
Market guarantee	Grain price	0.012	0.913	2.264	0.132	4.315	0.038**
	Yield	1.893	0.169	0.907	0.341	1.391	0.238
	Maturity	0.521	0.470	0.729	0.393	3.851	0.050*
	Drought	2.342	0.046**	0.372	0.542	8.379	0.004***
	Pest & disease resistance	0.968	0.325	0.018	0.894	2.652	0.103
	Grain size	2.649	0.041**	1.594	0.074*	0.700	0.403
	Grain colour	0.163	0.686	0.123	0.993	0.700	0.403
	Grain price	0.109	0.742	1.075	0.300	5.146	0.023**

Note: *** p<0.01, ** p<0.05, and * p<0.1

The findings from the study provide compelling evidence that traders' support services and seed attributes jointly influence the adoption of improved bean, sorghum and groundnuts varieties among smallholder farmers in Mubi region. These results support the argument that technology adoption in agriculture is not only a function of the innovation's inherent attributes but also of the institutional and market environments that surround the farmers, including the roles played by grain traders along the value chain (Spielman & Birner, 2008).

The results demonstrate that market-based support mechanisms such as access to market information, improved seed credit, input bundling credit, and market linkages play a crucial role in shaping how farmers prioritize seed attributes when deciding to adopt improved varieties. This aligns with earlier observations by Fisher *et al.* (2015) and Arouna *et al.* (2017), who argue that adoption decisions among smallholder farmers are rarely based on seed traits alone, but rather emerge from an interaction between varietal performance characteristics and the institutional or market incentives surrounding seed access and marketing.

For instance, market information support showed significant associations between adoption and yield, maturity, and grain price in groundnuts, and between grain size and adoption in sorghum. This implies that when farmers receive reliable information on the market demand for specific traits (e.g., large grain size or high-yield varieties), they are more likely to adopt improved varieties exhibiting those attributes. Similar findings were reported by Sperling and McGuire (2012), who noted that market signals and information networks substantially shape seed choice decisions. Likewise, Maredia *et al.* (2019) emphasized that knowledge flow through traders and other intermediaries reduces uncertainty about varietal performance and profitability, thereby facilitating adoption.

Seed credit support also emerged as a strong enabler of adoption, particularly influencing yield, maturity, drought tolerance, and grain price preferences across crops. These findings align with Abate *et al.* (2015), which found that access to input credit enhances farmers' ability to experiment with and adopt new technologies, particularly when liquidity constraints are binding. The significance of drought tolerance and pest resistance under improved seed credit and production loan arrangements underscores that risk-reducing attributes remain critical among smallholders operating in semi-arid environments.

Similarly, input bundling credit (where improved seeds are packaged with other inputs) significantly influenced adoption in relation to grain price and grain colour, especially in groundnuts. This suggests that input bundling credit not only reduces transaction costs but also encourages farmers to select varieties that align with market-preferred traits. Studies by Cunguara and Darnhofer (2011) and Martey *et al.* (2020) support this interpretation, showing that input bundled interventions simultaneously address multiple constraints access, affordability, and risk thus amplifying adoption impact.

Furthermore, market linkage support exhibited the strongest and most consistent associations across all three crops, particularly with grain size, yield, and drought tolerance. Farmers with assured market outlets were more likely to adopt improved varieties that meet buyers' quality standards. This finding echoes Fisher and Snapp (2014), who demonstrated that establishing market linkages and quality-based price incentives significantly increases adoption and sustained use of improved varieties. In a similar vein, Arouna *et al.* (2017) emphasized that integrating marketing arrangements and varietal traits creates a reinforcing loop, where demand for specific seed attributes drives adoption, and adoption, in turn, strengthens value chain coordination.

Lastly, market guarantees such as assured purchase agreements were significantly related to adoption based on drought tolerance and grain price, particularly in groundnuts. This pattern highlights the role of risk-sharing arrangements between traders and farmers in motivating adoption. By reducing post-harvest uncertainty, guarantees allow farmers to invest in quality seed that aligns with buyer preferences. Comparable evidence from Minten *et al.* (2020) and Smale *et al.* (2021) shows that contract farming and output market guarantees foster greater adoption of high-yield or quality-oriented varieties by mitigating marketing risks and stabilizing income expectations.

Overall, these results provide strong empirical support for the notion that seed adoption is a multi-dimensional process, jointly driven by technological traits (yield, maturity, drought tolerance) and institutional-market incentives (credit, market access, and information). The integration of these elements strengthens both short-term uptake and long-term varietal turnover, ensuring that farmers' preferences align with evolving market and climatic realities. The findings reaffirm calls by Fisher *et al.* (2015) and Arouna *et al.* (2017) for seed system interventions that blend demand-pull (market-driven) and supply-push (technology-driven) strategies to sustainably enhance adoption and impact among smallholder farmers.

CONCLUSION

This study provides empirical support for the integrated value chain and innovation diffusion perspectives, highlighting that, farmers are also likely to adopt improved varieties when traders' support services are combined with seed attributes that align with both agronomic performance and market expectations. Strengthening these synergies especially through flexible seed credit, bundled input packages, and improved market linkages could enhance the scaling up of improved seed technologies in Mubi region smallholder farming systems.

Enhancing the adoption of improved varieties in Mubi region, it is recommended that agricultural policies and programs promote integrated support services from grain traders and other seed development partners that are closely aligned with farmers' preferred seed attributes. Importantly, all interventions should be crop-specific and tailored to the unique needs and market dynamics of each value chain, in alignment with ADP for inclusive and market-led agricultural transformation.

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