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Evaluation of Productivity and Profitability of Newly Released Rice (*Oryza sativa* L.) Varieties in North-western Ethiopia: A Participatory Approach

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Abstract

The study focused on the evaluation of newly released improved rice varieties in North-western Ethiopia to fill the observed yield gaps due to low varietal promotion, access and inadequate agronomic practices. It was conducted at Pawe and Jawi districts during 2021-2022 production years. Experimental sites and target farmers were purposefully selected considering rice production potential, farmers' willingness and success prospects. Azmera, Pawe-2, and Fogera-1 varieties were evaluated using Nerica-4 as the standard check. Data were collected from 32 host and 32 non-host farmers (control) using data collection instruments with focus groups and direct field observation. The quantitative data were analyzed through descriptive statistics that comprise gross margin analysis, included Likert scales for the qualitative data. Findings revealed the highest (3742.04 kg ha^{-1}) mean grain yield was recorded from Azmera variety (642.04 kg over the national average) and 30,625.57 Birr ha^{-1} additional gross return obtained as compared to farmers' local practices. 1533.04 kg ha^{-1} extension gap was observed from Azmera variety. Overall, Azmera seemed promising in terms of its greater yield, profitability, and farmer preferences. Therefore, Azmera and Pawe-2 varieties are highly recommended for the large-scale production system along with their full production technologies and appropriate extension services to boost production and productivity.

Keywords: Demonstration, evaluation, margin, farmers' preference, rice variety

Introduction

Wheat, maize, and rice are the world's leading staple cereals and they constitute a significant component of the human diet, accounting for an estimated 42% of the world's calories and 37% of protein intake (Erenstein et al., 2022). Rice production has an impact on food security and socioeconomic status for more than half of the world's population (Mughal & Fontan Sers, 2020; Tang et al., 2022). The crop is not only a calorie source for half of the world's population, but it is also a crucial staple food for Asia and Africa's poorest and most malnourished people(Bin Rahman & Zhang, 2023). Rice is one of the world's most important food crops, as well as a promising and strategic commodity included in Ethiopia's food security strategy initiative (Delele et al., 2021). The crop is grown in Sub-Saharan African countries using various rice farming systems. Despite policy makers' increasing interest in ensuring sustainable rice production and significant research, little is known about the factors that influence the choice of various rice farming systems (Ouattara et al., 2022). It is a worldwide important food crop that is becoming economically important in Ethiopia as a result of a shift in feeding habits and integration with traditional food products. Because rice is a new crop, it is critical to improve research and development efforts in order to reduce the limited foreign currency required to import rice to meet rising local demand (Tadesse et al., 2019). Improving yield potential through the introduction of foreign elite lines/cultivars has been an important research objective; however, most new cultivars have been rejected by farmers due to poor grain quality compared to the traditional cultivars(Sekiya et al., 2020). This finding indicated that traditional cultivars' genetic resources should be thoroughly explored.

Cereal crops are the backbone of Ethiopian agriculture, providing food and a source of income for the country's rapidly rising population (Birhanu et al., 2022). Cereals are the most important crop class in Ethiopia in terms of area coverage, grain production volume, the number of smallholder farmers engaged in agriculture for a living and economic importance to the country's food security (Dessie, 2018). Adoption of improved rice varieties has a significant and positive effect on yield and commercialization of rice. The average effects of improved rice variety adoption on productivity was 0.564 t/ha, according to the findings of (Assaye et al., 2022). The availability of family labor, the age of the household head, the level of education of the household head, the distance to (market, rice seed source and agricultural extension service), credit service, and land size are all associated to the adoption of improved rice varieties to increase productivity (Hagos & Zemedu, 2015). The multi-stakeholder innovation platform strategy enhances smallholder farmers' marketing decision making (Ouma et al., 2020).

Despite the fact that North-western Ethiopia's Metekel and Awi zones have tremendous potential for rice production, present production levels are far below consumption and market demand due to poor production and productivity. The actual rice production from Metekel zone has been practiced from Pawe district and Jawi from the Awi zone. Average productivity of rice in the two zones (Pawe and Jawi) was 2209.00 kg per hectare which is far from the national average (3100.00 kg ha^{-1}). Aside from the availability of untapped rice potential in these areas and throughout the nation, the Pawe and Fogera Agricultural Research Centres, in collaboration with the collaborative research centres, released about 40 different rice varieties which are suitable in the upland and lowland ecosystems. However, very few rice varieties were in the hands of producers due to many factors, including variety incompatibility with farmers' needs and restricted varietal promotion, and weak rice seed supply system. Currently, the rice research program, in cooperation with other experts and farmers, has released and identified Azmera, Pawe-2, and Fogera-1 rice varieties that have the respective potential yields of 4800, 5100 and 4200 kg ha^{-1}. These varieties particularly Azmera and Pawe-2 have a significant yield advantage and other merits over varieties currently in production. The identified materials have been evaluated under smallholder farmers' management conditions during the experiment period of 2021-2022 years across multiple locations to obtain evidence and build confidence for recommending the varieties for large-scale production. Accordingly, the respective experimental trial yields of Azmera, Pawe-2 and Fogera-1 were 3742.04, 3385.81 and 3125.63 kg ha^{-1} and the mean grain yield of farmers those who have produced rice using the local seeds coupled with the conventional farming operations was 2209.00 kg ha^{-1}. This showed that the significant extension gaps (EG) of 1533.04, 1176.81and 916.63 kg ha^{-1} were recorded from Azmera, Pawe-2 and Fogera-1 rice varieties, respectively. The on-farm experiments conducted in farmers' fields were completed successfully with promising results, and the outsmart varieties that were tested and evaluated with farmer participation, taking into account their preferences, were recommended to be applied into the large-scale production system to improve producer production and productivity. Hence, this research was begun and carried out to generate adequate evidence on the feasibility and productivity of the demonstrated varieties while taking farmers' preferences into account in pursuit of filling the yield gaps observed in the study areas.

Materials and Methods

Description of the Study Area

The evaluation was conducted in the Pawe and Jawi districts of North-western Ethiopia during 2021-2022 cropping years. The two districts were purposively selected for the demonstration because of their agro-ecological similarity and great rice potential. Pawe and Jawi are located 567 and 602 kilometers away from Addis Ababa, respectively. The total area of Pawe is 64,300 hectares, of which 50.4% are arable and used for crop production whereas 515,400 hectares for Jawi. The respective altitudes of Pawe and Jawi districts are 1120 and 700-1500 meter above seas level. Pawe is geographically located at $36^0$27’21.88’’-$36^0$28’22.95’’ longitude and 11^0 20’04.93’’-$11^0$17’50.43’’latitude and $36^0$29’17.58’’ longitude and $11^0$33’22.68’’latitude are the coordinates of Jawi. According to the districts report (2022), the respective populations of Pawe and Jawi districts were 69,263 (51.68% male) and 134,485 (53.08% male). The entire Jawi and Pawe kebeles are known for their great rice potential that is why many commercial farmers particularly at Jawi district are engaged in rice production at large-scale. Indeed, almost all smallholder farmers in these areas produce rice each year both for consumption and marketing purposes. Maize, sorghum, rice, soybean, groundnut, and sesame are the dominant crops grown in these areas. The people of these areas have a mixed farming system, involving both crop production and livestock rearing. Sells of cattle (live animal and butter byproducts) and goats from small ruminants are the main cash sources for farmers at critical times to purchase agricultural inputs for their production and to cover labor expenses particularly for weeding and harvesting.

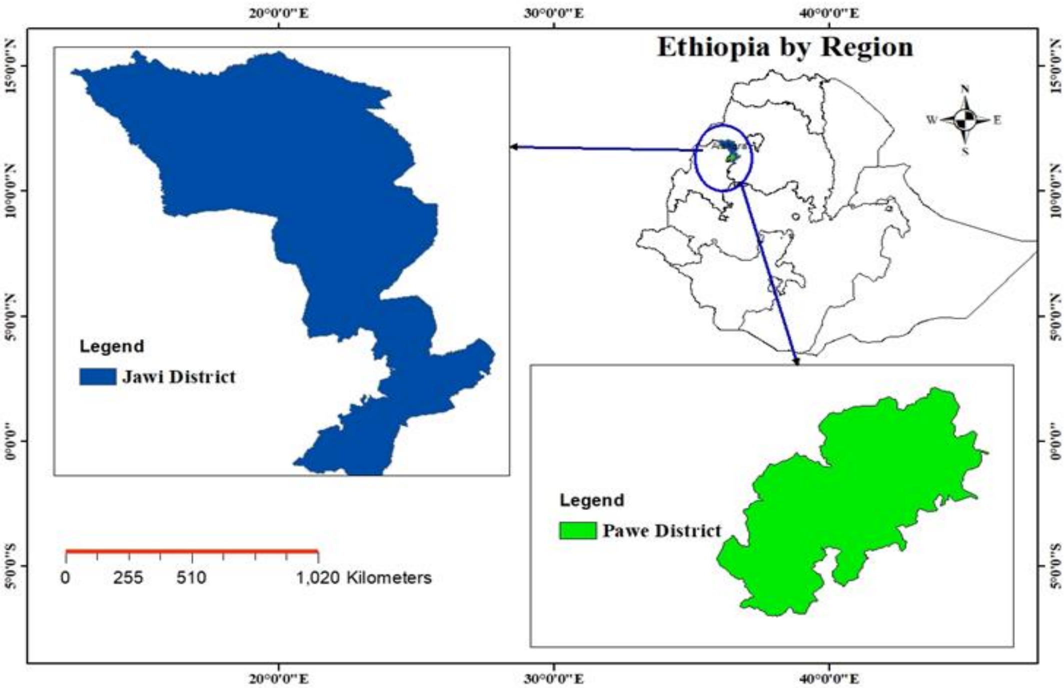
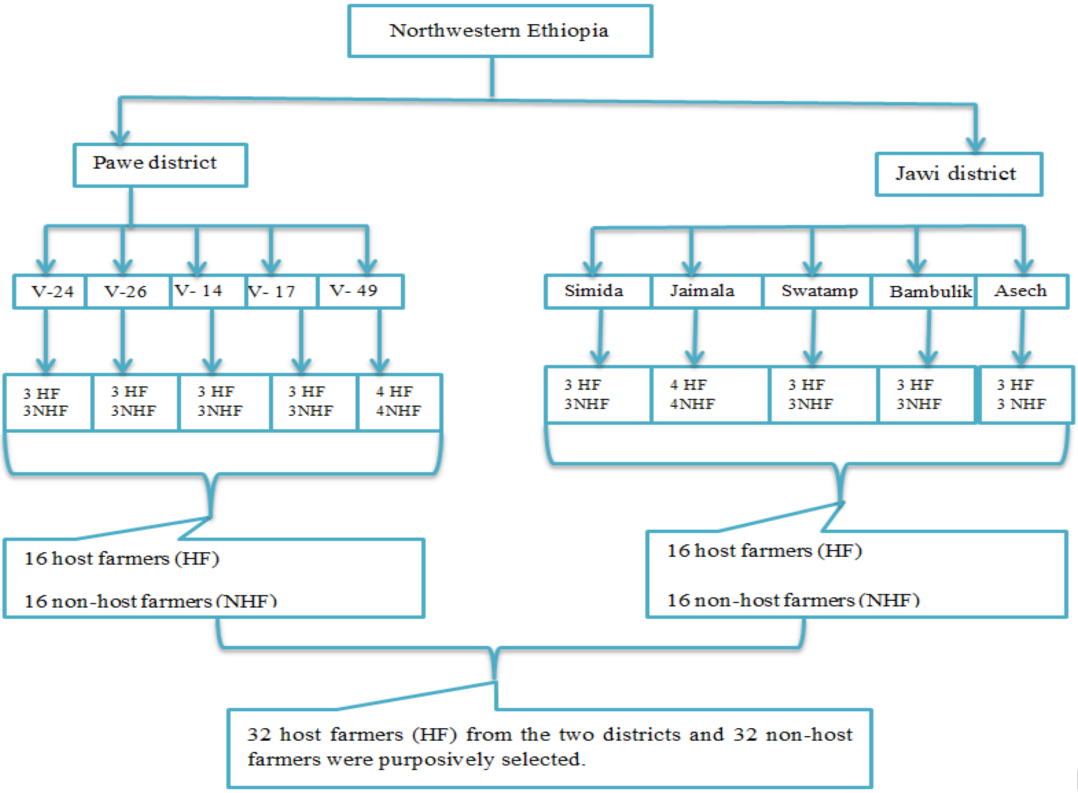


Figure 1. Geographical location of the study areas (North-western Ethiopia)

Techniques of Farmer and Site Selection

The pre-extension demonstration (PED) was carried out in the Pawe and Jawi districts because of the availability of more suitable land for rice production during the 2021/22 and 2022/23 consecutive production years. Target kebeles and host farmers were purposively selected from each district considering rice production potential, farmers' willingness and success to implement the demonstration and prior experience of their farming operations, and representativeness. Accordingly, 10 kebeles and 32 host farmers/ experimental sites in the two districts were selected in close collaboration with each district experts and development agents (Figure 2). The number of farmers who participated in the demonstration was considered a replicate. Each host farmer prepared a 25 m × 25 m (625 m^2) plot of land for each variety. Moreover, 32 farmers who grew rice using local seeds coupled with their conventional farming operations were purposively selected as a control group, and data were gathered from the two districts. The demonstration was conducted for two years to capture the seasonal variation of the varieties regarding their performances over location. The Pawe Agricultural Research Center organized a follow up team by considering the team composition from different disciplines. This team closely monitored, supervised and evaluated PED activities starting from site selection to post-harvest handling techniques to meet the stated objectives. Overall, agricultural extension researchers played a leading role in the PED coordination and implementation processes.

Figure 2. Details of host and non-host farmers per district at each kebele



Materials Used in the Evaluation

In the overall implementation of the pre-extension demonstrations, Azmera, Pawe-2 and Fogera-1 varieties were used considering Nerica-4 as a standard check. These varieties have been performed very well in the upland ecosystem. All the demonstrated verities are found at medium maturity class with attractive white seed colors. The recommended package of technologies, which comprise a seed rate of 80 kg ha^{-1} and fertilizer rates of 100 kg ha^{-1} NPS and 150 kg ha^{-1} UREA, sowing method, sowing time, disease or high yielding attribute if any, were applied, respectively. PARC trained host farmers, experts, and extension agents on how to properly implement the whole recommended packages of improved rice production and protection practices. Planting and other farming operations were done accordingly with close follow up of researchers and DAs.

Table 1. General description of the demonstrated varieties

Evaluated varieties	Year of release	Maturity class	Maturity date	Yield at research field (kg ha^{-1})	Production Ecosystem	Seed colour
Azmera	2019	Medium	114	4800.00	Upland	White
Pawe-2	2020	Medium	118	5100.00	Upland	White
Fogera-1	2016	Medium	105-120	4200.00	Upland	White
Nerica-4	2006	Medium	110	4800.00	Upland	White

Source: Pawe Agricultural Research Center, Rice Breeding Program, 2022

Methods of Data Collection

The data were collected from site selection to the completion of the pre-extension demonstrations. Data on variety performances in terms of yield gathered from all host farmers, including the farmers in the control group. The productivity and revenues of the demonstration and control plots were compared. All demographic, socio-economic, and agronomic data were gathered using the prepared data collection tools. Farmers' perceptions and preferences were also collected during field day (result demonstration) events and on the spot at different stages of the PED implementation over the last two seasons. In the evaluation processes, farmers, researchers, and experts were directly involved, and the outsmart varieties were identified by combining farmers' and experts' preferences from different perspectives for further large-scale production. Interviews (individual and group) and direct field observations were used to collect the required data by triangulating focus groups. Overall feedback on the demonstrated varieties was carefully recorded and well documented. Additionally, data were collected from 32 non-host farmers who grew rice using locally available seeds coupled with conventional farming practices to use as a control group.

Methods of Data Analysis

The quantitative data was analyzed through descriptive and inferential statistics coupled with gross margin analysis using SPSS (version 27) software package. The qualitative data (perception & preferences) of farmers were analyzed using Likert scale including pairwise analysis.

Yield, Extension and Technology Gap Analysis

Yield gap analysis was generally done to quantify the additional yield that could be produced with the given level of resources & improved technologies. Yield gap arises due to the difference in efficiency and management practices. The research carried out by (Ali et al., 2022; Delele et al., 2021) on technology gap assessment and productivity gain through front line demonstration in groundnut and evaluation on newly released improved haricot bean varieties were followed similar procedures for the estimation of gap analysis.

Technology Gap (TG) = Potential yield – Average demonstration plot yield

Extension Gap (EG) = Average demonstration plot yield – Average farmer's plot yield

Technology Index = $\frac{(P_i - D_i)}{P_i}\ x\ 100\%$

Where Pi is the potential yield of rice crop and Di is the average demonstration plot yield.

Percent of yield increase over farmer's practice = $\frac{\textbf{Average demo plot yield} - \textbf{Farmer's average plot yield}}{\textbf{Farmer's average plot yield}}\ x\ 100$

Profitability Analysis

The economics of cultivation for each technology demonstrated can be estimated at PED stage before recommended to the large-scale production. The feasibility of the demonstrated technologies was estimated to increase the rate of technology adoption through convincing farmers and other stakeholders. The technology is said to be economically feasible, if the profits are higher compared to those of farmer's practice and it's given by the following formulae.

TR (I) – TR (F) > TC (I)-TC (F)

ΔR (I) > ΔC (F)

TR = ∑Pi.Yi

TC = ∑Pj.Xj

Where, TR (I) is the total returns received from improved technology plot
TR (F) is the total returns of farmer's local practice plot
TC (I), the total cost incurred from improved technology plot
TC (F), the total cost incurred from farmer' local practice plot
ΔR (I), the change in returns from the improved technology plot
ΔC (F), the change in cost of farmer's local practice plot
Gross margin/profitability analysis
Gross profit (GP) = Sales Revenue (SR) – Total variable costs (TVC)

$$\text{Gross profit margin (GPM)} = \frac{\text{Gross Profit (GP)}}{\text{Sales Revenue (SR)}} \times 100\%$$

$$\text{Benefit} - \text{cost ratio (BCR)} = \frac{\text{Sales Revenue (SR)}}{\text{Total Variable Cost (TVC)}}$$

Where, GP, is the gross profit of farmers
SR, is the sales revenue
TVC, is total variable cost
GPM, gross profit margin
BCR, benefit-cost ratio

Results and Discussion

Farmers' Preference Traits of the Varieties

The findings shown in Table 2 demonstrated the mean scores for each rice variety in terms of the 11 traits of preference that farmers and experts had found. Each variety received a rating for each attribute before being ranked based on the average of all the scores. The bottom Table's rating scale, which varied from 1 (poor) to 5 (excellent), is shown. The Pawe-2 variety produced the highest total mean score (4.29), followed by Azmera (4.20). The Pawe-2 variety received the highest rating for tillering capacity, seed color, grain yield, seed size, disease resistance, market demand, logging resistance, and panicle length. The least rating score received for Pawe-2 was shattering resistance and maturity date. Similar to this, Azmera variety received the maximum rating score (4.07-4.59) in all preference traits except maturity date (3.81). Azmera variety highly resists shattering including logging unlike Pawe-2. The overall mean score showed that the Pawe-2 variety was primarily chosen by farmers and experts during the maturity stage evaluation. Based on the overall mean score results of farmers' preference traits, the Fogera-1 variety was the farmers' last choice in all testing sites throughout the season. The result is similar to (Assaye et al., 2023; Belayneh & Chondie, 2022).

Table 2 Mean score results of the varieties for farmers' preference traits

Preference traits	Mean score results of the varieties for each trait			
(N = 75)	Pawe-2	Azmera	Fogera-1	Nerica-4
Grain yield	4.55	4.07	2.57	2.60
Seed size	4.27	4.33	3.08	3.15
Seed colour	5.00	4.12	3.13	3.27
Tillering capacity	5.00	4.13	2.41	3.05
Disease resistance	4.48	4.16	3.39	3.35
Market demand	4.71	4.17	3.41	3.47
Biomass yield	4.6	4.15	2.73	3.00
Maturity date	2.97	3.81	3.71	3.65
Shattering resistance	2.6	4.36	3.36	3.53
Logging resistance	4.27	4.59	4.08	3.55
Panicle length	4.73	4.27	2.63	3.08
Overall Mean Score	4.29	4.20	3.14	3.25
Preference Rank	1st	2nd	4th	3rd

Rates: 1 = poor, 2 = moderate, 3 = Good, 4 = Very good & 5 = Excellent
Source: own data computation, 2021-2022

The newly released rice varieties have been thoroughly evaluated under smallholder farmer conditions over the last two years, with active farmer and expert participation. Farmers, researchers, and experts found eleven preference traits to choose rice varieties. The traits found for variety preferences were grain yield, seed size, seed color, tillering capacity, disease resistance, market demand, biomass yield, maturity date, shattering resistance, logging resistance, and panicle length. 75 farmers took part in the comparison of traits using pairwise comparison chart analysis to choose the best trait and were given a 1 for the best trait and a 0 otherwise. Disease resistance was rated first in terms of trait preference importance, followed by grain yield and market demand, according to the results of a pairwise comparison. Following the traits stated above, shattering resistance, tillering capacity, panicle length, and seed color have all become important traits. The finding is in line with (Asrat et al., 2010; Miriti et al., 2023; Nakyewa et al., 2021; Ndeko et al., 2022; Semahegn et al., 2021). The trait was ranked based on its total value, as shown in Table 3. The least significant trait was biomass yield. Although farmers have many cattle and small ruminants in the study areas, feed shortage is not presently a problem because there are many freely grazing lands available in the areas, which could explain why rice biomass yields are the least significant trait for the time being.

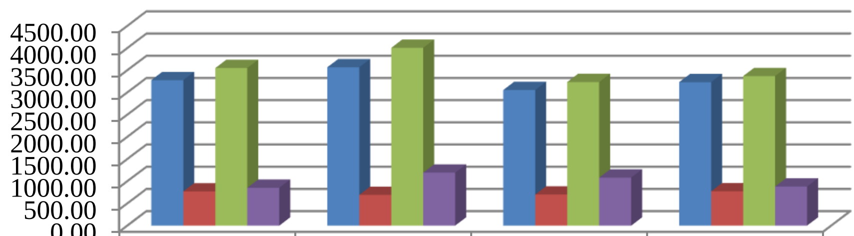
Table 3. Pairwise comparison of farmers' preference traits in the study areas

	GY	SSZ	SCO	TCP	DR	MD	BY	DM	SR	LR	PLG	TS	Rank
GY		1(73)	1(72)	1(70)	0(74)	1(71)	1(74)	1(74)	1(64)	1(73)	1(71)	9	2nd
SSZ	0		0(58)	0(70)	0(74)	0(55)	1(74)	1(68)	0(66)	0(73)	0(66)	2	9th
SCO	0	1		0(74)	0(74)	0(66)	1(74)	1(63)	0(74)	0(66)	1(73)	4	7th
TCP	0	1	1		0(74)	0(66)	1(74)	1(57)	0(60)	1(58)	1(73)	6	5th
DR	1	1	1	1		1(74)	1(74)	1(74)	1(74)	1(74)	1(74)	10	1st
MD	0	1	1	1	0		1(74)	1(74)	1(53)	1(43)	1(43)	8	3rd
BY	0	0	0	0	0	0		0(74)	0(74)	0(74)	0(74)	0	11th
DM	0	0	0	0	0	0	1		0(74)	0(43)	0(65)	1	8th
SR	0	1	1	1	0	0	1	1		1(70)	1(58)	7	4th
LR	0	1	1	0	0	0	1	1	0		1(69)	5	9th
PLG	0	1	0	0	0	0	1	1	0	0		3	6th

BY = biomass yield, DR = diseases resistance, GY = grain yield, DM = Days of maturity, MD = market demand, LR = logging resistance, SCO = seed colour, PLG = panicle length, SR = shattering resistance, SSZ = seed size, TCP = tillering capacity and TS = total score

Figure 3. Performance of rice pre-extension demonstration at Jawi district

Findings of the demonstration showed that the highest mean grain yield recorded from Azmera variety followed by Pawe-2 over season. Mean grain yield of 3566.67 and 4005.10 kg ha^{-1} had found from Azmera variety in year one and two respectively (Figure 4). The respective of 3276.44, 3231.20 and 3053.61 kg ha^{-1} mean grain yield obtained from Pawe-2, Nerica-4 and Fogera-1 varieties in year one. Similar to this, 3549.86, 3367.50 and 3233.65 kg ha^{-1} mean grain yield recorded from Pawe-2, Nerica-4 and Fogera-1 varieties respectively in year two. The result implies that better mean grain yield observed from year two compared to year one and this may be due to absence of stalked eye fly and relatively good rain fall distribution in year two.



	Pawe-2	Azmera	Fogera-1	Nerica-4
Year one Mean	3276.44	3566.67	3053.61	3231.20
Year one SD	770.50	692.19	699.80	772.82
Year two Mean	3549.86	4005.10	3233.65	3367.50
Year two SD	851.81	1192.98	1081.20	880.69

Figure 4. Mean grain yield of the demonstrated varieties over season

Yield, Yield Gap and Extension Gap Analysis

The results of the demonstration showed that the highest mean grain yield recorded from Azmera variety in all experimental sites. Findings revealed that 3876.31 and 3540.64 kg ha^{-1} mean grain yield recorded from Azmera variety in Pawe and Jawi districts respectively. Pawe-2 variety was the second high yielder variety following Azmera and the respective of 3478.15 and 3247.29 kg ha^{-1} yield had found in Pawe and Jawi districts. As the results depicted in the Table 4 below, 3388.80 kg ha^{-1} from Pawe and 3131.11 kg ha^{-1} mean grain yield at Jawi observed from Nerica-4 variety. The least mean grain yield observed from Fogera-1 variety in most testing locations of Pawe and Jawi districts. According to the results of the combined analysis over location, the highest (3742.04 kg ha^{-1}) mean grain yield observed from Azmera variety followed by Pawe-2 (3385.81 kg ha^{-1}). 3285.72 & 3125.63 kg ha^{-1} mean grain yield recorded from Nerica-4 and Fogera-1 varieties respectively. The least mean grain yield also observed from Fogera-1 variety which is similar to farmers' preference that had been done at evaluation stage. The overall findings of the experiment over season and across location revealed that Azmera variety is highly promising both in terms of its great yield advantage and farmers' preference followed by Pawe2.

Azmera variety showed that 487.51 and 409.53 kg per hectare yield advantage over the standard check at Pawe and Jawi districts respectively. The combined analysis over location also indicated that 456.32 kg ha^{-1} yield increment over the standard check observed from Azmera variety followed by Pawe-2. Pawe-2 also had 100.09 kg ha^{-1} yield advantage over the standard check. Fogera-1 variety showed negative yield advantage compared to the standard check in Pawe and Jawi districts. The maximum technology gap (TG) observed from Pawe-2 variety both in Pawe (1621.85 kg ha^{-1}) and Jawi (1852.71 kg ha^{-1}) districts over season followed by Nerica-4. The combined analysis over location indicates that 1714.19 kg ha^{-1} TG recorded from Pawe-2 variety and the least (1057.96 kg ha^{-1}) TG observed from Azmera variety. The findings of the demonstration revealed that the maximum extension gap (EG) had found from Azmera variety both in Pawe and Jawi districts. The respective extension gap (EG) of 1653.31 and 1345.64 kg ha^{-1} recorded at Pawe and Jawi districts. The combined analysis over location also showed that the highest (1533.04 kg ha^{-1}) extension gap (EG) observed from Azmera variety followed by Pawe-2. Although the highest EG recorded from Azmera variety, all the demonstrated varieties showed great EG in all experimental sites. The great extension gap and the higher technology index revealed that the productivity of farmers' local practice is extremely low. Use of local variety seeds, low level of fertilizer rate and limited applications of other recommended production packages might be the possible reasons of obtaining the great EG in all locations. Agricultural extension programs significantly boosted the productivity of farms and household income (Danjumah et al., 2024; Danso-Abbeam et al., 2018; Emmanuel et al., 2016; Kamruzzaman et al., 2021; Maake & Antwi, 2022).

Table 4. Yield and yield gap analysis over locations

District	Variety	Potential Yield	PED yield	Farmers' Local yield	YI over check	TG	EG	T. Index (%)
Pawe	Pawe-2	5100.00	3478.15	2223.00	89.35	1621.85	1255.15	31.8
	Azmera	4800.00	3876.31	2223.00	487.51	923.69	1653.31	19.24
	Fogera-1	4200.00	3199.26	2223.00	-189.54	1000.74	976.26	23.83
	Nerica-4	4800.00	3388.80	2223.00	--	1411.2	1165.8	29.4
Jawi	Pawe-2	5100.00	3247.29	2195.00	116.18	1852.71	1052.29	36.33
	Azmera	4800.00	3540.64	2195.00	409.53	1259.36	1345.64	26.24
	Fogera-1	4200.00	3015.18	2195.00	-115.93	1184.82	820.18	28.21
	Nerica-4	4800.00	3131.11	2195.00	--	1668.89	936.11	34.77
Combined	Pawe-2	5100.00	3385.81	2209.00	100.09	1714.19	1176.81	33.61
	Azmera	4800.00	3742.04	2209.00	456.32	1057.96	1533.04	22.04
	Fogera-1	4200.00	3125.63	2209.00	-160.09	1074.37	916.63	25.58
	Nerica-4	4800.00	3285.72	2209.00	--	1514.28	1076.72	31.55

EG = extension gap, PED = pre-extension demonstration, TG = technology gap, T. index = technology index & YI = yield increase

Source: Own data computation, 2021-2022

The results of the demonstration over season and across location revealed that significant yield advantage had found from Azmera variety compared to both in the local and national average. Findings showed that 1533.04 kg ha^{-1} from the local average and 642.04 kg ha^{-1} from the national average yield advantage observed from Azmera variety (IPAD, 2023). The rest evaluated varieties also reveal a significant yield increment over the local average and slightly higher than the national average (Figure 5).

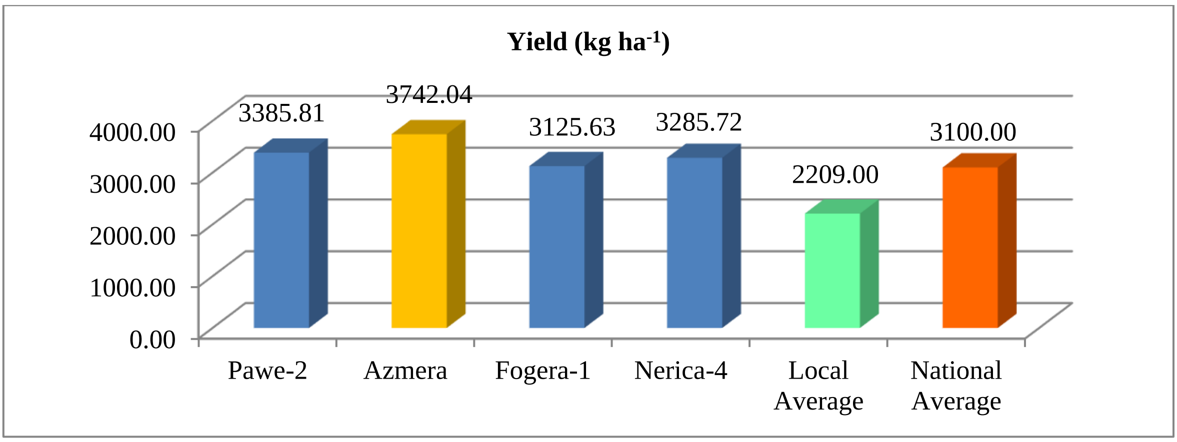


Figure 5. Yield comparison of the demonstrated varieties with the local and national average yields

Mean Comparison of the Varieties

The results of the demonstration revealed that 3742.04, 3385.81, 3285.72 & 3125.63 kg ha^{-1} mean grain yield recorded from *Azmera*, *Pawe-2*, *Nerica-4* and *Fogera-1* varieties respectively (Table 5). The combined analysis over season and across location showed that highly significant mean difference observed between Azmera and all other the demonstrated varieties regarding mean grain yield. The result of t-test (t = 3.357) is an evidence for the presence statistical mean difference between Azmera and Pawe-2 varieties regarding the quantity of grain yield obtained per hectare. Similar to this, (t = 3.345 & 4.794) indicate significant mean difference between Azmera & Nerica-4 and Azmera & Fogera-1 respectively. The result of t-test (t = 1.801) also indicates the existence of statistical difference between Pawe-2 and Fogera-1 variety at (P < 0.1) in terms of mean grain yield. The overall findings of the study indicates that Azmera variety is highly promising and preferred by farmers and experts in terms of its great yield advantage and other preference traits.

Table 5. Yield comparison of the demonstrated varieties

Comparisons	Variety	Mean (kg ha^{-1})	SD	t-value	Sig. (2-tailed)
Pawe-2 Vs Fogera-1	Pawe-2	3385.81	801.1225	1.801*	0.082
	Fogera-1	3125.63	859.3833		
Pawe-2 Vs Nerica-4	Pawe-2	3385.81	801.1225	0.826^{NS}	0.415
	Nerica-4	3285.72	805.5563		
Azmera Vs Pawe-2	Azmera	3742.04	931.8918	3.357***	0.002
	Pawe-2	3385.81	801.1225		
Azmera Vs Nerica-4	Azmera	3742.04	931.8918	3.345***	0.002
	Nerica-4	3285.72	805.5563		
Azmera Vs Fogera-1	Azmera	3742.043	931.8918	4.794***	0.000
	Fogera-1	3125.628	859.3833		
Nerica-4 Vs Fogera-1	Nerica-4	3285.72	805.5563	1.175^{NS}	0.249
	Fogera-1	3125.63	859.3833		

SD = standard deviation
Source: Own experiment data, 2021-2022

Gross Margin Analysis

The production cost of rice is increasing at increasing rate over time. Seed, fertilizer, chemicals, land preparation to sowing, weeding, harvesting and threshing were the production costs of rice in the study areas. Results of the demonstration indicate that the production cost of rice was 24013.43 and 27446.91 Birr per hectare at Pawe and Jawi districts respectively during 2021/22 production season (Table 6). The combined result over location showed that the total production cost was 25730.17 Birr per hectare in the same cropping year. However, the respective production cost of rice in Pawe and Jawi districts was 34782.96 and 38281.76 Birr per hectare in 2022/23 production year. The combined analysis over location indicates that the total production cost was 36532.36 Birr per hectare which implies that 41.98% production cost increment observed compared to the starting year of 2021/22 production season. Fertilizer and input purchase costs showed highly significant increase over time. The result agrees with (Mottaleb & Mohanty, 2015). The combined result over location revealed that the purchase price of fertilizer was increased from 3741.50 to 9633.00 Birr per hectare which is close to three fold compared to year I. Similar to this, the purchase price of improved seeds increased from 1680.00 to 3956.00 Birr per hectare which is more than doubled. This implies that 157.46% and 135.48% purchase price increment observed from fertilizer and improved rice seeds respectively. Land preparation including sowing, weeding, harvesting, threshing, and chemical production costs showed slightly increasing.

Table 6 Production cost of rice PED over season and across location

List of costs incurred	Production cost distribution per district over season (ETB/ha)					
	Pawe		Jawi		Combined	
	Year I	Year II	Year I	Year II	Year I	Year II
Seed	1680.00	3956.00	1680.00	3956.00	1680.00	3956.00
Fertilizer	3763.50	9638.00	3719.50	9628.00	3741.50	9633.00
Chemical	776.18	988.72	870.27	1086.88	823.23	1037.80
Land preparation	5600.00	6238.40	6000.00	6400.00	5800.00	6319.20
Weeding	10068.75	11528.72	12720.00	14424.48	11394.38	12976.60
Harvesting	1043.75	1195.09	1142.86	1296.00	1093.30	1245.55
Threshing	1081.25	1238.03	1314.29	1490.40	1197.77	1364.22
Prod_ cost	24013.43	34782.96	27446.91	38281.76	25730.17	36532.36

Year I = 2021/22 cropping season & Year II = 2022/23 cropping season
Source: Own data computation, 2021-2022

As the results depicted in Table 7, the maximum gross revenue observed from Azmera variety which is 96,210.01 and 88,321.26 Birr per hectare in Pawe and Jawi districts respectively due to its great yield advantage compared to the rest of the varieties. The least gross revenue observed from Fogera-1 variety both in Pawe and Jawi districts. The results of the combined analysis over location showed that the respective total variable costs of Azmera, Pawe-2, Nerica-4 and Fogera-1 were 32858.60, 32694.16, 32647.96 & 32574.06 Birr per hectare. A gross profit of 65261.29 and 53604.47 Birr per hectare received in Pawe and Jawi districts respectively from Azmera variety. The combined data over location indicates that 60252.71 Birr ha^{-1} gross profit received from this variety with a gross profit margin of 64.71% followed by Pawe-2 (51553.26 Birr ha^{-1}). The respective gross profit of 49108.97 and 45199.43 Birr ha^{-1} obtained from Nerica-4 and Fogera-1 varieties. Although the highest gross profit observed from Azmera variety over location, better and attractive net benefit received from all the demonstrated varieties and this might be due to the increasing market price of rice over time both in the domestic and global markets. The increasing rate of the production cost and gross profit of rice was not comparable implying that the increasing rate of gross profit is higher compared to the rate of the production cost over time. The finding is consistent to (Akite et al., 2022; Mauki et al., 2023). Good government initiative and polices coupled with diversion of households' rice consumption make rice more attractive and feasible for producers.

Table 7 Net benefits of rice production over location

District	Varieties	Yield (kg ha^{-1})	MC (ETB 100kg^{-1})	MC (ETB ha^{-1})	Production cost	Variable cost	Gross revenue	Gross profit	GPM (%)
Pawe	Pawe-2	3478.15	40.00	1391.26	29398.20	30789.46	86327.68	55538.22	64.33
	Azmera	3876.31	40.00	1550.52	29398.20	30948.72	96210.01	65261.29	67.83
	Fogera-1	3199.26	40.00	1279.70	29398.20	30677.90	79405.63	48727.73	61.37
	Nerica-4	3388.8	40.00	1355.52	29398.20	30753.72	84110.02	53356.30	63.44
Jawi	Pawe-2	3247.29	52.32	1698.98	32864.34	34563.32	81003.65	46440.33	57.33
	Azmera	3540.64	52.32	1852.46	32864.34	34716.80	88321.26	53604.47	60.69
	Fogera-1	3015.18	52.32	1577.54	32864.34	34441.88	75213.67	40771.79	54.21
	Nerica-4	3131.11	52.32	1638.20	32864.34	34502.53	78105.54	43603.01	55.83
Combined	Pawe-2	3385.81	46.16	1562.89	31131.27	32694.16	84247.42	51553.26	61.19
	Azmera	3742.04	46.16	1727.33	31131.27	32858.60	93111.31	60252.71	64.71
	Fogera-1	3125.63	46.16	1442.79	31131.27	32574.06	77773.49	45199.43	58.12
	Nerica-4	3285.72	46.16	1516.69	31131.27	32647.96	81756.93	49108.97	60.07

ETB = Ethiopia Birr, GPM = gross profit margin & MC = marketing cost
Source: Own data computation, 2021-2022

The results indicated in Table 8 show that the pre-extension demonstration (PED) and farmers' local practice in the 2021/22 production season had production costs of 25730.17 and 20565.41 Birr ha^{-1}, respectively, with an additional cost of 5164.76 Birr per hectare due to PED intervention. Similar to this, the farmers' local practice and PED had respective production costs of 26710.53 and 36532.36 Birr ha^{-1} during the 2022–23 crop years, with an additional cost of 9821.83 Birr due to PED. The combined analysis over season also showed that PED and farmers' local practices resulted in production costs of 31131.27 and 23637.97 Birr per hectare. Additional cost of 7493.30 Birr per hectare incurred as a result of the PED intervention since it uses the fully recommended production packages. The Azmera, Pawe-2, Nerica-4, and Fogera-1 varieties each produced a gross profit of 59850.28, 51703.30, 49414.24, and 45752.98 Birr ha^{-1} during the 2021/22 crop season. The gross profits received from all the demonstrated varieties in year II (2022/23) was better than year I (2021/22). The reasons for increasing gross profits could be due to the increasing market price and better productivity of rice. Due to absence of stalked eye fly infestation and good rain fall distribution in year II made rice good in productivity. Although the production costs of rice significantly increasing over time, productivity improvement and output market price increment made attractive and feasible gross profit for rice producers. The combined analysis over season showed that the Azmera, Pawe-2, Nerica-4, and Fogera-1 varieties produced gross profit of 61980.04, 53116.15, 50625.66, and 46642.22 Birr per hectare, respectively.

As a result of PED intervention in the 2021/22 crop year, additional gross profits of 29895.86, 21748.88, 19459.82, and 15798.56 Birr ha^{-1} were recorded from Azmera, Pawe-2, Nerica-4 and Fogera-1 varieties respectively. The combined analysis over season shows that the Azmera, Pawe-2, Nerica-4, and Fogera-1 varieties provided additional gross profits of 30652.57, 21788.68, 19298.19, and 15314.75 Birr per hectare, respectively. Moreover, the PED intervention's benefit-cost ratio (BCR) was considerably higher than the benefit cost ratio of farmers' local practices. Azmera is the most economically feasible variety, followed by Pawe-2, and is very promising for future large-scale production even though the benefit cost ratio and net returns of all the demonstrated varieties are better than the farmers' local practice. The finding is similar to (Akanbi et al., 2024; Chhom et al., 2023). The overall findings of the economic analysis showed that the PED's increased production costs are lower than the PED intervention's increased net returns. According to the results, PED generated substantial additional net returns while only adding some amount to production costs.

Table 8. Additional costs and net returns of rice production over season due to PED intervention

Variety	Cultivation cost in year one (2021/22)						BCR	
	PED	Local	Additional cost of PED	Gross revenue	Gross profit	AGP of PED	PED	Local
Pawe-2	25730.17	20565.41	5164.76	77433.47	51703.30	21748.88	3.01	2.46
Azmera	25730.17	20565.41	5164.76	85580.45	59850.28	29895.86	3.33	2.46
Fogera-1	25730.17	20565.41	5164.76	71483.16	45752.98	15798.56	2.78	2.46
Nerica-4	25730.17	20565.41	5164.76	75144.42	49414.24	19459.82	2.92	2.46
	Cultivation cost in year two (2022/23)							
Pawe-2	36532.36	26710.53	9821.83	91061.36	54529.00	21828.47	2.49	1.89
Azmera	36532.36	26710.53	9821.83	100642.17	64109.81	31409.28	2.75	1.89
Fogera-1	36532.36	26710.53	9821.83	84063.82	47531.46	14830.93	2.30	1.89
Nerica-4	36532.36	26710.53	9821.83	88369.44	51837.08	19136.55	2.42	1.89
	Combined analysis over season							
Pawe-2	31131.27	23637.97	7493.30	84247.42	53116.15	21788.68	2.71	2.33
Azmera	31131.27	23637.97	7493.30	93111.31	61980.04	30652.57	2.99	2.33
Fogera-1	31131.27	23637.97	7493.30	77773.49	46642.22	15314.75	2.50	2.33
Nerica-4	31131.27	23637.97	7493.30	81756.93	50625.66	19298.19	2.63	2.33

AGP = additional gross profit, BCR = benefit cost ratio & PED = pre-extension demonstration

Constraints of Rice Varietal Promotion

Rice producers are facing several challenges regarding rice technology adoption even though the crop becomes the national priori commodities. Socio-economic factors, physical, biological, technological and institutional factors hamper the processes of technology adoption and promotion (Delele et al., 2021). Weed infestation, diseases and pests, accelerated increment of inputs cost (seed, fertilizer and agro-chemicals) can discourage farmers from adopting and continue in rice production by using the improved varieties coupled with full production packages. Incompatibility of the varieties with the farmers' needs also another inhibiting factor for adopting the new varieties. Great gap has been observed in implementing full agronomic practices among farmers particularly those who have produce rice using local seeds along with conventional farming operations. This implies that without the application of full production packages, productivity cannot be boosted by using the improved varieties alone.

Conclusion and Recommendation

The main purpose of this study was evaluating the newly released improved rice varieties to reveal the performance and profitability in North-western Ethiopia. The promising varieties of rice were identified based on farmer preferences and the yield advantage over the standard check. Azmera rice variety had the greatest yield gain and gross profit of 61680.04 Birr per hectare with a gross profit margin of 64.71% in all districts during the season, followed by Pawe-2. It was chosen not only for its high yield increase over the control, but also for its other quantitative and qualitative traits in all testing sites throughout the season. The variety outperforms and primarily chosen by farmers for further large-scale production to improve their production and productivity due to its high yield increment, most economical feasibility, and other qualitative traits. Findings showed a significant extension gap (1533.04 kg ha^{-1}) in most locations when compared to the technology gap, indicating that the productivity of farmers' local practices is extremely low due to poor agronomic and other management practices, aside from the use of local variety seeds.

The Azmera rice variety outperforms in terms of farmer preferences, yield advantage, and economic feasibility, as well as other quantitative and qualitative traits. Pawe-2 is also the second most promising and preferred rice variety among farmers, both in terms of yield and farmer choice. As a result, these two rice varieties are strongly advised for inclusion in a large-scale production system to boost producer production and productivity with its full production packages. Therefore, the zone and district agricultural offices will stress the use of Azmera and Pawe-2 rice varieties in large-scale production systems in order to fill production and productivity gaps in the region and throughout the nation. To close the large extension gaps noted in the production system, the district, zone, and regional agricultural offices must revise the delivery system of agricultural extension advisory services to farmers and experts.

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