Registration of 'Pawe-2' Rice Variety for Upland Ecosystem in Ethiopia

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Abstract

Background: Rice (*Oryza sativa* L.) is produced in Ethiopia. However, the national average yield is far below the potential of the crop due to, among others, limited availability of stable, high yielding and disease tolerant upland rice varieties. This problem has seriously limited production of the crop in the country.

Objective: The research was conducted to evaluate and release a stable high yielding and disease resistant/tolerant upland rice varieties for the typical upland rice ecosystems in Ethiopia.

Material and Methods: The rice variety (currently named *Pawe-2*) introduced from Brazil in 2012 was evaluated along with *NERICA-4* and *Fogera-1* as local and standard check varieties, respectively, at Pawe and Metema (typical upland rice ecosystems) beginning from a 2013. After the evaluation of the variety for six years, verification trials were conducted in 2019 and in 2020.

Results: *Pawe-2* had better performances for most agronomic traits than the check varieties. The newly released variety, *'Pawe-2'* had an average grain yield of 5058.93 kg ha^{-1}, and it had yield advantages of 15.68% and 13.52% over *Fogera-1* and *NERICA-4* rice varieties, respectively, as shown by the results of the verification trails conducted in 2019. Moreover, *Pawe-2* had a higher biomass yield, larger grain size, white caryopsis color, early maturity and resistance to diseases and pests than the check varieties.

Conclusions: It is concluded that the variety *'Pawe-2'* is superior to the other varieties in terms of yield, yield stability, and resistance to pests and diseases. Therefore, the National Variety Release Committee approved *Pawe-2* for cultivation in the mid altitude (750–1800 meters above sea level) and similar typical upland rice ecosystems in Ethiopia.

Keywords: Early maturing; Grain yield; Upland rice variety; Verification and yield advantage

1. Introduction

Rice (*Oryza sativa* L.) is a cereal commonly used as a staple food crop for a significant part of human population. It provides 27% of the calories in the world's low and middle-income countries (Fukagawa and Ziska, 2019). The rice production system is classified into lowland and upland rice. In lowland rice, fields are usually flooded during part or all of the growing season; lowland rice includes rain-fed lowland, irrigated lowland, deep-water and mangrove swamp (Saito *et al*., 2013). Upland rice grows on level or sloping, unbunded fields and flooding is rare in this system. In some cases, especially in Latin America, supplemental irrigation may be used. Upland rice is grown under crop rotation systems with other crops, or under slash-and-burn systems (Atlin *et al*., 2006; Pinheiro *et al*., 2006; Saito *et al*., 2006). Recent statistics from 71 countries from Asia, Latin America, and sub-Saharan Africa show that lowland and upland rice account

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ISSN 1993-8195 (Online), ISSN 1992-0407(Print)

for 92 and 8% of total rice cultivation area, respectively (Saito *et al.*, 2018).

Rice is one of the most strategic crops in Africa, and particularly in Ethiopia (Meron Abebe, 2016). Ethiopia has immense potential for growing rice. In 2019/20 *Meher* season, 178,185 households produced rice on 57,575.72 hectares of land and produced a total of 170, 630.1 tons with average yield of 2.964 t ha^{-1}. The total area cultivated for rice has reduced by 9.13%, but the total yield has reduced only by 0.71% and the national average yield has increased by 0.252 ton (9.29%) than 2018/19 main production season (CSA, 2020). The increase of average national yield with a one-season change seems showing the productivity of the crop is fast growing, but it is still low as compared to its potential. This is due to biotic and abiotic stress including limited number of varieties available to withstand major biotic and abiotic stress. In this regard, Pawe and Metema agricultural research centers have been working on the development of upland rice varieties with high yield potential, early maturity and resistance to major rice diseases (blast, brown spot, sheath blight, bacterial panicle blight and sheath spot) and pests (Taye Tadesse *et al.*, 2019).

Evaluation of introduced rice varieties and available genotypes over locations and seasons is one the breeding methods to develop high yielding upland rice varieties in Ethiopia. Accordingly, the introduced variety from Brazil in 2012 was evaluated along with the existing rice varieties over locations and seasons to test the cultivation value of the variety in Ethiopia. The introduced variety was found to be superior to the existing rice varieties for yield and other desirable agronomic traits and approved for cultivation by the National Variety Release Committee in 2020 named as *Pawe-2* upland rice variety. This paper presents the overall performances of the recently released upland rice variety (*Pawe-2*) aiming at providing information for all actors in rice production in Ethiopia.

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2. Varietal Evaluation

Three varieties having unique characters like high grain yield, long grain size, early maturity, and disease and pest resistance were introduced from Brazil in 2012. The varieties are commercially cultivated in Brazil. The three introduced varieties and two standard check varieties, *NERICA-3* and *NERICA-4* were evaluated during 2013 to 2015 main cropping seasons in northwestern Ethiopia specifically at PARC (Pawe Agricultural Research Center). During a preliminary yield evaluation trial, PARC.DAT.V-3.2013 was identified as a candidate variety (*Pawe-2*) since it outperformed the standard check varieties and other two introduced varieties. The candidate variety and other genotypes, a total of 17 genotypes were advanced to national variety trial and evaluated across locations for two years. The standard check was *NERICA-4* released in 2006 in Ethiopia. The genotypes were evaluated at major upland rice growing areas, namely, Fogera (Woreta), Gondar (Metema), Pawe, Assosa (Kamashi), and Shire (Mai-tsebri) for two years (2016/2017 to 2017/2018) in a randomized complete block design (RCBD) with three replications. In 2018/2019 cropping season, PARC.DAT.V-1.2013 as candidate variety-1 and PARC.DAT.V-3.2013 as candidate variety-2 (Pawe-2) along with *NERICA-4* and *Fogera-1* as local and standard check varieties, respectively, were evaluated for verification at seven test sites. The National Variety Release Committee evaluated the varieties on the field.

Pawe-2 consistently outyielded the other tested rice varieties over three years. The average yield of *Pawe-2* was 5033.01kg ha^{-1} in 2013 up to 2015 main cropping seasons (Table 1). Combined years over locations analysis revealed that *Pawe-2* produced an average yield of 4984.50 kg ha^{-1} during 2016–2017 cropping season (Table 3). *Pawe-2* also showed superior overall agronomic performances over the standard check (*Fogera-1*) and the local check (*NERICA-4*) varieties under verification trial. Likewise, it proved to be more resistant for leaf blast, panicle blast, and brown spot; and scored less damage by different insects like termite and stalk eye fly than the check varieties. The results of the over locations and seasons revealed that, *Pawe-2* was superior in grain yield performance, protein content, and diseases resistance. Thus, the recommendation of *Pawe-2* for cultivation was reasonable and it is important to register as a commercial variety to promote its production in typical upland rice ecosystems. In the same manner, Girma Mengistu *et al.* (2013) were evaluated the pipeline upland rice genotypes against the standard check viz., Superica-1, across six environments during the 2012 main cropping seasons and the variety “Chewaka” showed superior performance over the other pipelines and recommended by the National Variety Released Committee to be registered as a variety. Similarly, Famoso *et al.* (2019) reported the Registration of ‘PVL01’ Rice as evaluated the rice genotypes across seven environments for resistance to Provisia herbicide, containing the active ingredient quizalofop, an AACase (group 1) herbicide.

3. Agronomic and Morphological Characters

Pawe-2 showed a higher number of tillers per plant, a larger number of field grain per panicle, larger-sized seeds, higher grain yield and better resistance to diseases and pests than the standard check (*Fogera-1*) during the variety verification trial. *Pawe-2* is distinguished by a white seed color and long seed size, and thousand-grain weight of 12.34 grams. It attained 50% heading, 50% heading, 50% flowering, and 85% maturity in 80, 84 and 118 days, respectively, after emergence. It had panicle length of 21.09 cm and plant height of 97.51 cm (Tables 4 and 5) with the average number of fertile tillers per plant of 6.4. Harrell *et al.* (2021) reported the registration of different rice varieties following similar research methods and the rice varieties registered had a higher number of tillers per plant, a larger number of field grain per panicle, larger-sized seeds, a higher grain yield and better resistance to different rice diseases.

4. Yield Performance

Pawe-2 was produced a higher average mean grain yield (5033.01 kg ha^{-1}) than *NERICA-4* (4405.02 kg ha^{-1}) and *NERICA-3* (4305 kg ha^{-1}) during the three years (2013–2015) evaluation (Table 1). *Pawe-2* had a higher yield advantage of 14.26% and 16.89% over *NERICA-4* and *NERICA-3* varieties, respectively. It also produced a higher grain yield than the standard check (Fogera-1) and local check (NERICA-4) during the variety verification trial in 2018/2019 main cropping season at seven sites (Table 4). *Pawe-2* variety had a higher biological yield (55414.29 kg ha^{-1}) than the two check varieties *Fogera-1* (44214.29 kg ha^{-1}) and *NERICA-4* (43996.67kg ha^{-1}) (Table 4). Consistent with these results, Harrell *et al.* (2021) reported the registration of different rice varieties that had higher yield advantages than the standard and the local checks as tested in more year and seasons.

5. Reaction to Pest and Disease

Pawe-2 was superior in tolerance to diseases (leaf blast, panicle blast and brown spot) and sustained less termite and shoot fly damage compared to the check varieties (*Fogera-1* and *NERICA-4*). Significantly lower termite damage of 21% was recorded to *Pawe-2* than the *Fogera-1* (43%) and NERICA-4(50%) check varieties (Tables 2 and 4), and in 2018/2019 cropping season, the four genotypes did not show any symptoms of the disease. Consistent with this result, Harrell *et al.* (2021) reported similar findings. Rice leaf blast (*Magnaporthe grisea*) is a key concern in combating global food security given the disease is responsible for approximately 30% of rice production losses globally-the equivalent of feeding 60 million people (Nalley *et al.*, 2016). These losses increase the global rice price and reduce consumer welfare and food security. Even, rice brown spot (*Helminthosporium oryzae*) is a chronic disease that affects millions of hectares of rice every growing season, grown by some of the most resource-poor farmers. Brown spot is conventionally perceived as a secondary problem that affects rice crops that experience physiological stresses, e.g., drought and poor soil fertility, rather than a true infectious disease (Barnwal *et al.*, 2013). Therefore, BS is by far one the strongest yield reducers amongst rice diseases today. The range of reported yield losses to BS, often expressed in relative terms, is variable from 26 to 52% (Chakrabarti, 2001).

Table 1. Combined mean grain yield and other agronomic traits for upland rice genotypes in Pawe at two locations over three years (2013–2015).

S/N	Variety	DH	DM	PH (cm)	PL (cm)	FTP	FGP	GY (kg ha^{-1})	TSW(g)
1	PARC DAT-V1-2013	78.21	113.11	90.54	22.16	9.52	145.58	4838.16	26.15
2	PARC DAT-V2-2013	81.5	111.15	91.50	23.26	8.51	139.65	4715.56	26.01
3	PARC DAT-V-3-2013	82.5	114.20	87.08	23.05	8.05	143.48	5033.01	25.90
4	NERICA-3	73.5	112.5	82.5	21.25	7.15	135.8	4305.5	24.8
5	NERICA-4 (Check)	71.23	109.00	84.30	21.15	8.45	137.78	4405.02	25.00
	Mean	77.388	111.992	87.184	22.174	8.336	140.458	4659.45	25.572
	Maximum	82.5	114.2	91.5	23.26	9.52	145.58	5033.01	26.15
	Minimum	71.23	109	82.5	21.15	7.15	135.8	4305.5	24.8

Note: *DH = Days to 50% heading; DM = Days to 85% maturity; PL = Panicle length (cm); PH = Plant height (cm); FTP = Fertile tillers/plant; FGP = Filled grains/panicle; GY = Grain yield (kg ha^{-1}); and TSW (g) = Thousand seed weight.*

Table 2. Mean values of different diseases reaction scores (0–9) of the genotypes in Pawe at two locations over three years (2013–2015).

S/N	Variety	Leaf rust		Panicle blast		Brown spot		Sheath rot	Termite damage (%)
		Seedling	Tillering	Dough	Maturity	Tillering	Milk stage		
1	PARC DAT-V1-2013	0	0	1	0	0	0	0	2.0
2	PARC DAT-V2-2013	0	0	0	0	1	0	1	1.6
3	PARC DAT-V-3-2013	0	0	0	1	0	0	0	1.5
4	NERICA-3	1	1	0	0	1	1	0	4.5
5	NERICA-4 (Check)	1	0	0	0	0	0	0	3.5

Note: *0 = Highly resistant and 1 = Resistance reactions.*

Table 3. Combined mean grain yield and other yield related parameters of 17 upland rice genotypes during 2016-2017cropping season.

S/N	Genotypes (G)	Code	DH	DM	PH	PL	FTP	FGP	GY (kg ha^{-1})
1	NM1-29-4-B-P-80-8	G1	73	101	93.04	21.38	5.85	130.14	4845.50
2	ART16-9-29-12-1-1-2-B-1-1	G2	73	101	102.77	20.91	6.78	120.79	3965.60
3	ART16-9-14-16-2-2-1-B-1-2	G3	69	98	93.96	22.24	5.98	117.46	4745.80
4	ART16-9-33-2-1-1-1-B-1-2	G4	77	104	98.87	21.13	6.23	127.92	4834.30
5	ART16-9-122-33-2-1-1-B-1-1	G5	75	102	97.90	20.73	6.74	117.33	4885.80
6	ART15-19-5-4-1-1-1-B-1-1	G6	75	102	96.28	21.34	6.10	110.43	4658.00
7	ART16-5-9-22-2-1-1-B-1-2	G7	76	102	95.27	19.99	6.20	126.85	5027.20
8	ART16-21-4-7-2-2-2-B-2-2	G8	73	101	94.46	20.95	6.14	125.79	4717.90
9	ART16-9-16-21-1-2-1-B-1-1	G9	76	101	102.07	21.64	5.87	114.26	4902.50
10	ART15-13-2-2-2-1-1-B-1-2	G10	73	99	92.54	21.61	6.49	114.47	3762.10
11	ART15-16-45-1-B-1-1-B-1-2	G11	74	101	96.56	21.53	5.86	189.89	4398.60
12	ART16-5-10-2-3-B-1-B-1-1	G12	75	101	102.30	21.98	6.19	122.80	4603.20
13	ART16-4-1-21-2-B-2-B-1-2	G13	76	103	97.12	21.23	6.19	130.41	4516.80
14	PARC.DAT.V-1.2013	G14	78	104	97.64	21.37	7.12	131.74	4528.00
15	PARC.DAT.V-2.2013	G15	79	104	99.68	22.14	7.00	125.19	4207.40
16	PARC.DAT.V-3.2013	G16	79	106	99.29	21.92	6.02	129.73	4984.50
17	NERICA-4(Check)	G17	72	101	93.09	20.56	6.99	124.67	4712.70
Mean			74.80	101.85	97.26	21.32	6.36	126.42	4617.88
CV (%)			3.76	2.19	7.93	7.92	23.63	27.21	16.67
LSD (5%)			1.97	1.57	5.41	1.18	1.05	24.12	539.91
Genotype (G)			***	***	***	**	NS	NS	***
Environment (E)			***	***	***	***	***	***	***
Genotype x Environment (G x E)			NS	NS	NS	NS	NS	NS	**

Note: *DH = Days to 50% heading; DM = Days to 85% heading; PL = Panicle length (cm); PH = Plant height (cm); FTP = Number of fertile tillers per plant; FGP = Number of filled grains per panicle; and GY = Grain yield (kg ha^{-1}). ** and *** refer to significant level at P < 0.01 and 0.001, respectively, and NS = not significant at P < 0.05.*

Table 4. Mean grain yield, other agronomic traits and diseases reaction of PARC.DAT.V-1.2013 (candidate-1), PARC.DAT.V-3.2013, *Pawe-2* (candidate-2) and the check varieties during multi-location evaluation in 2019/2020.

Traits	Candidate-1	Candidate-2	NERICA-4	Fogera-1
Days to 50% heading	81.57	80.43	71.86	72.00
Days to 50% flowering	85.43	84.14	75.14	75.14
Days to 85% maturity	121.57	117.86	106.14	105.00
Plant height (cm)	94.84	97.51	87.00	89.66
Panicle length (cm)	20.31	21.09	19.66	19.57
Number of fertile tillers/plants	6.03	6.40	4.83	4.71
Number of unfertile tillers/plants	0.06	0.11	0.20	0.14
Number of filled grain/panicles	147.53	152.17	137.06	140.8
Number of unfilled grain/panicles	4.60	4.59	4.11	3.91
Grain yield (kg ha^{-1})	4727.50	5058.93	4456.24	4372.9
1000 seed weight	12.07	12.34	11.36	11.53
Moisture content	27.79	28.04	26.79	26.86
Stand count	670571.43	731714.29	600857.14	624857.14
Biological yield (kg ha^{-1})	51885.71	55414.29	43996.67	44214.29
Termite damage (%)	0.21	0.21	0.50	0.43
Leaf blast at seedling	0.00	0.00	0.00	0.00
Leaf blast at tillering	0.00	0.00	0.00	0.00
Panicle blast at dough stage	0.00	0.00	0.00	0.00
Panicle blast at maturity stage	0.00	0.00	0.00	0.00
Brown spot at tillering	0.00	0.00	0.00	0.00
Brown spot at milk stage	0.00	0.00	0.00	0.00
Sheath rot	0.00	0.00	0.00	0.00

Table 5. Morpho-agronomic characteristics of *Pawe-2* upland rice variety.

Variable	Description
Variety name:	*Pawe-2*
Agronomic and morphological characteristics:	
Adaptation area	Pawe, Fogera, Assosa, Gondar, Maitsebri and other similar agro-ecologies of Ethiopia.
• Altitude (m.a.s.l.) [a]	750–1860
• Rainfall (mm)	1100–1457
Seed rate (kg ha^{-1})	60
Planting date	mid-June to early July depending on the onset of rainfall
Spacing(cm)	25 cm between rows for row drill planting
Fertilizer rate (kg ha^{-1}) and time of application	N = 69 (1/3 at planting, 1/3 at tillering and 1/3 at panicle initiation) and P_2O_5 = 23 (all at planting)
Days to heading	80
Days to maturity	118
Panicle length(cm)	21.1
Plant height(cm)	97.5
Thresh ability	Easy
Lodging incidence	None
Shattering	Moderately Resistant
Seed size(mm)	Slender shape [length (9.2): width (2.5) =7.14]
Growth habit	Erect
No. of grains per panicle	152
1000 seed weight (g)	12.34
Caryopsis color	White
Crop pest reaction	Resistant to major rice diseases
Grain yield (kg ha^{-1})	
Research field	5059
Farmers field	4847
Year of release	2020
Breeder/maintainer:	Pawe Agricultural Research Center /EIAR

Note: [a] *m.a.s.l. = meters above sea level.*

6. Other Quality Traits

In the major rice-consuming countries, grain quality characteristics dictate the market value of the commodity and play an important role in the development and adoption of new varieties. Grain quality includes such traits as physical appearance and nutritional values. The rice varieties were mainly developed based on yield and other desirable traits. However, *Pawe-2* contains has also good nutritional values like protein, fat and ash, and better market-oriented variety than the tested genotypes. The average kernel length of the variety was higher than other tested varieties with a higher protein content (4.79%) (Atsedemariyam Tewachew *et al.*, 2018).

7. Conclusion

The results of this study have demonstrated that *Pawe-2* is a high yielding variety, resistant to major rice diseases such as blast and brown spot. Moreover, the variety has a greater number of tillers per plant, a greater number of filled grains per plant, longer grains and white caryopsis color. Its grain is also relatively rich in protein, ash and fat. Generally, the variety has traits preferred by farmers as confirmed by their positive feedback during the evaluation and verification trials. Hence, it is necessary to promote the variety in typical upland rice growing areas of Ethiopia.

8. Acknowledgements

The authors thank the Ethiopian Institute of Agricultural Research for providing financial supports to evaluate and release the variety and Fogera National Rice Research and Training Centre for cooperating and coordinating the evaluation trials across locations. The authors also appreciate the technical staff of rice improvement program of Pawe, Fogera, Gondar-Metema Research Centers for smooth implementation of the trials over the years.

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