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Research paper

Upland rice variety development for Ethiopia

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Productivity of rice in Ethiopia is increasing with consistent deployment of new improved varieties into production. However, the productivity levels attained in both research managed fields as well as farmers' fields are low compared to world average. This makes variety development critical. In an effort to develop upland rice variety, two independent pipelines were set. One was targeting the upland & high elevation environments, while the other one the typical upland. Both pipelines followed the established variety development and evaluation procedures of the research system in the country. Single site analysis was used for preliminary variety trials to promote promising genotypes to the national variety trials. Multi-environment analysis was employed to select candidate genotypes to be verified and for possible approval by the National Variety Releasing Committee (NVRC). In both sets, promising genotypes were identified at the preliminary variety trials and promoted to national variety trials. Results of the upland national variety trial showed that two genotypes (ART16-5-9-22-2-1-1-B-1-2 and ART16-9-33-2-1-1-1-B-1-2) found promising and promoted to verification and approval. These candidates outsmarted the standard check in terms of high grain yield, earliness and larger grain size. ART16-5-9-22-2-1-1-B-1-2 has been approved and registered by the NVRC and named Azmera as vernacular name. It showed more than 10% yield advantage compared to the standard check. Azmera is an improved variety profiled with high grain yield, earliness, larger grain size and white caryopsis. It is recommended to be produced in lower altitude and high temperature areas such Pawe, Assosa, Metema and similar agro-ecologies.

Key words: *azmera, high elevation, rice, upland, variety*

INTRODUCTION

Rice is increasingly important in Ethiopia, which could be evidenced by consistent increments of domestic production and imports (Alemu et al., 2018). It seems a surprise that why the import is consistently increasing while the volume of domestic production, which is mainly due to productivity increase, area expansion and increasing number of farmers in rice cultivation, is increasing? (ECSA, 2018) This could be attributed to many factors such as the increase in consumption rate of rice in the country surpasses the rate of increase of domestic production and quality requirement of the consumer does not met with the domestic produce. The low quality of the domestic produce could be associated with the varieties developed so far do not profiled with most of the preferred attributes, postharvest processing problems and skill gaps in rice value chain actors. Although productivity of rice in the country is increasing with consistent deployment of new improved varieties into production (ECSA, 2017; MoANR, 2017), but still the productivity levels attained in both research managed fields as well as farmer's fields are low compared to both elsewhere in the world and the potential.

Furthermore, biotic production constraints such as sheath rot and blast are significantly impacting rice productivity. Thus, variety development considering those attributes related with consumer preference and biotic and abiotic production constraints is critical.

The national rice research program targets three production environments; namely, rain-fed lowland, rain-fed upland and irrigated rice growing ecosystems. The upland rice ecology spans wider areas in the northwestern part of the country. These include, Pawe, Metema, Gambella, Assosa, Chewaka, Guraferda and Mytsebri. The national rice research program in collaboration with other rice implementing centers released 15 improved rice varieties targeted to the upland production environment (Dessie et al., 2019). The present variety development and evaluation effort aimed at development and release of a variety with high yield, resistant or at least tolerant to sheath rot and blast, white caryopsis color, large grain size and with good biomass yield compared to the standard upland rice variety.

MATERIALS AND METHODS

Study locations

Quarantine and field observations were carried out at Andassa center. Early stage evaluations (observation nurseries and preliminary yield trails) were made at limited locations, usually at Fogera. Multi-location evaluations were conducted at seven different locations in the north, Northwest and Western parts of Ethiopia; namely, Mytsebri, Gondar, Fogera, Pawe, Assosa, Kamashi, Bako-Chewaka and Bonga-Guraferda. Detail descriptions of study locations are provided in Table 1 below.

Table 1. Description of study locations

Location	Altitude (m)	Satellite Coordination		Annual rainfall	Temperature ^{0}c (Mean)	
					Maximum	Minimum
1	1707	11^0 29' N	37^0 29' E	1489.65	30.4	14.5
2	1810	11^{0}58'N	37^{0}41'E	1300	27.9	11.5
3	1050	11^{0}09'N	36^{0}3'E	1457	32.8	17.2
4	1590	10^{0}03'N	34^{0}59'E	1120	28.0	14.5
5	1250	10^{0}04'N	34^{0}56'E	1200	31.5	17.0
6	750	12^{0}54'N	36^{0}15'E	1100	29.0	22.0
7	NA	NA	NA	NA	NA	NA
8	1138	6^{0}50'N	35^{0}17'E	1332	39.0	25.0
9	1350	11^{0}08'N	38^{0}08'E	1296	36.0	15.0

Location 1 – Andassa, Location 2- Fogera, Location 3- Pawe, Location 4- Assosa, Location 5- Kamashi, Location 6- Metema, Location 7- Chewaka, Location 8-Guraferda, Location 9- Shire/ Maitsebri, NA - not available; Source, Authors own compilation

Plant materials

One hundred thirty four genotypes were introduced from Africa Rice Center in 2014. Among which, 102 were targeted for upland and high elevations and the remaining once for just upland, hence the observations were set into two independent sets of experiments. They were checked for quarantine pests; and observations were made by group of researchers including breeders and a pathology. Based on the evaluations, many of the test materials were promising and composed into a preliminary variety trails (PVT) and these trails were carried out at Fogera as two independent sets of experiments. Promising materials at this evaluation stage further promoted and composed into a national variety trail (NVT), which were carried out in a muli-location trial for two years. A variety verification trial (VVT) for the upland set was undertaken and it was visited by the national variety technical committee. Lists of the genotypes included in the PVTs, NVTs and VVT (Tables 2 – 5).

Table 2. List of genotypes included in Upland and high elevation PVT

Genotype code	Genotype designation
1	ART15 2-21-3-3-2-1-B-B-1
2	ART15 6-16-44-1-B-1-B-B-1
3	ART15 8-10-36-4-1-1-B-B-1
4	ART15 10-17-46-2-2-2-B-B-2
5	ART15-16-31-2-1-1-1-B-1-1
6	ART15-21-2-4-1-B-1-B-1-1
7	ART15-21-30-1-1-1-B-1-2
8	ART16 5-10-22-4-B-1-B-B-1
9	ART16 9-4-18-3-1-1-B-B-1
10	ART16 9-16-21-1-B-2-B-B-1
11	ART16 9-29-10-2-B-1-B-B-1
12	ART16-4-1-21-2-B-2-B-1-1
13	ART16-4-13-1-2-1-1-B-1-1
14	ART16-4-2-2-2-B-1-B-1-1
15	ART16-4-5-5-1-1-1-B-2-1
16	ART16-4-8-17-3-1-1-B-1-1
17	ART16-5-10-2-3-B-1-B-1-2
18	ART16-5-11-13-1-2-1-B-1-2
19	ART16-5-9-22-2-1-1-B-1-1
20	ART16-9-1-9-2-1-1-B-1-1
21	ART16-9-1-13-1-3-1-B-1-1
22	ART16-9-1-13-1-3-1-B-1-2
23	ART16-9-4-18-4-2-1-B-1-1
24	ART16-9-4-18-4-2-1-B-1-2
25	ART16-9-5-28-3-13-1-B-2-1
26	ART16-9-6-18-1-1-2-B-1-1
27	ART16-9-8-32-3-3-1-B-2-2
28	ART16-9-9-25-2-1-1-B-2-1
29	ART16-9-9-25-2-1-1-B-2-2
30	ART16-9-11-11-3-2-1-B-1-2
31	ART16-9-19-11-2-2-2-B-1-1
32	ART16-9-19-11-2-2-2-B-1-2
33	ART16-9-19-13-4-B-1-B-1-2
34	ART16-9-22-1-2-B-1-B-1-1
35	ART16-9-22-1-2-2-1-B-1-2
36	ART16-9-24-4-4-2-1-B-5-2
37	ART16-9-25-30-3-2-2-B-1-1
38	ART16-9-26-21-3-2-1-B-2-2
39	ART16-9-27-31-2-1-1-B-1-1
40	ART16-9-29-10-4-2-1-B-1-1
41	ART16-9-29-16-1-1-1-B-1-1
42	ART16-9-33-5-4-B-1-B-1-2
43	ART16-10-17-16-2-B-1-B-1-2
44	ART16 12-22-3-1-2-1-B-B-1
45	ART16 13-11-14-3-1-1-B-B-1
46	ART16 15-10-1-1-B-1-B-B-1
47	ART16 15-10-1-1-B-1-B-B-2
48	ART16-12-22-1-3-1-1-B-1-2
49	ART16-12-22-3-1-B-1-B-1-1

50	ART16-12-22-3-1-B-1-B-1-2
51	ART16-12-25-23-1-1-3-B-1-1
52	ART16-12-28-32-3-B-1-1-2
53	ART16-12-28-32-4-B-1-B-3-1
54	ART16-12-28-32-4-B-1-B-3-2
55	ART16-13-11-1-2-B-2-B-2-1
56	ART16-13-13-2-2-B-1-B-1-1
57	ART16-13-14-1-1-1-1-B-1-1
58	ART16-13-14-1-1-1-1-B-1-2
59	ART16-14-1-33-2-B-1-B-1-1
60	ART16-14-2-31-1-1-2-B-2-1
61	ART16-14-2-31-1-1-2-B-2-2
62	ART16-15-9-2-1-B-1-B-2-1
63	ART16-15-9-2-1-B-1-B-2-2
64	ART16-16-1-14-3-1-1-B-1-1
65	ART16-16-1-14-3-1-1-B-1-2
66	ART16-16-5-23-1-2-1-B-1-2
67	ART16-16-11-25-1-B-1-B-1-2
68	ART16-17-7-18-1-B-1-B-1-1
69	ART16-21-5-12-3-1-1-B-2-1
70	ART16-21-13-32-1-1-1-B-1-1
71	NERICA-4
72	NERICA-12

Table 3. List of genotypes included in upland PVT

Genotype code	Genotype designation
1	ART15-13-2-2-2-1-1-B-1-1
2	ART15-13-2-2-2-1-1-B-1-2
3	ART15-16-12-3-1-B-1-B-3-1
4	ART16-5-9-22-2-2-1-11-B-1-2
5	ART16-19-5-4-1-1-1-B-1-1
6	ART16-4-1-21-2-B-2-B-1-2
7	ART16-21-5-12-3-1-2-B-1-2
8	ART16-5-10-2-3-B-1-B-1-1
9	ART16-9-1-32-1-1-1-B-1-2
10	ART16-9-4-18-3-2-1-B-1-1
11	ART16-9-12-33-4-1-1-B-1-2
12	ART16-9-14-16-2-2-1-B-1-2
13	ART16-9-16-21-1-2-1-B-1-1
14	ART16-9-22-1-2-2-1-B-1-1
15	ART16-9-26-21-3-2-1-B-2-1
16	ART16-9-29-10-4-1-1-B-1-1
17	ART16-9-29-12-1-1-1-B-1-1
18	ART16-9-29-12-1-1-2-B-1-1
19	ART16-9-29-16-1-1-1-B-1-2
20	ART16-9-33-2-1-1-1B-1-2
21	ART16-9-122-33-2-1-1-B-1-1
22	ART16-12-13-28-5-1-1-B-1-1
23	ART16-16-45-1-B-1-1-B-1-2
24	ART16-13-11-1-2-B-2-B-2-2
25	ART16-13-14-1-1-1-1-B-1-1
26	ART16-16-11-25-1-B-1-B-1-1
27	ART16-17-8-6-4-1-1-B-2-2
28	ART16-21-4-7-2-2-2-B-2-2
29	NM7-7-8-2-B-P-11-6
30	NM1-29-4-B-P-80-8
31	NARICA 4
32	NERICA 12

Table 4. List of genotypes included in upland and high elevation NVT

Genotype code	Genotype designation	Source
1	ART15-16-31-2-1-1-1-B-1-1	AfricaRice
2	ART16 5-10-22-4-B-1-B-B-1	AfricaRice
3	Fogera 1 (Check 1)	Released variety in Ethiopia
4	ART16 9-29-10-2-B-1-B-B-1	AfricaRice
5	ART16-4-13-1-2-1-1-B-1-1	AfricaRice
6	ART16-9-5-28-3-13-1-B-2-1	AfricaRice
7	ART16-9-9-25-2-1-1-B-2-1	AfricaRice
8	ART16-9-19-11-2-2-2-B-1-2	AfricaRice
9	ART16-9-25-30-3-2-2-B-1-1	AfricaRice
10	ART16-12-28-32-3-B-1-1-2	AfricaRice
11	NERICA-4 (Check 2)	Released variety in Ethiopia

Table 5. List of genotypes considered in upland NVT

Genotype code	Genotype designation	Source
1	NM1-29-4-B-P-80-8	AfricaRice
2	ART16-9-29-12-1-1-2-B-1-1	AfricaRice
3	ART16-9-14-16-2-2-1-B-1-2	AfricaRice
4	ART16-9-33-2-1-1-1-B-1-2	AfricaRice
5	ART16-9-122-33-2-1-1-B-1-1	AfricaRice
6	ART15-19-5-4-1-1-1-B-1-1	AfricaRice
7	ART16-5-9-22-2-1-1-B-1-2	AfricaRice
8	ART16-21-4-7-2-2-2-B-2-2	AfricaRice
9	ART16-9-16-21-1-2-1-B-1-1	AfricaRice
10	ART15-13-2-2-2-1-1-B-1-2	AfricaRice
11	ART15-16-45-1-B-1-1-B-1-2	AfricaRice
12	ART16-5-10-2-3-B-1-B-1-1	AfricaRice
13	ART16-4-1-21-2-B-2-B-1-2	AfricaRice
14	PARC.DAT.V-1.2013	Brazil
15	PARC.DAT.V-2.2013	Brazil
16	PARC.DAT.V-3.2013	Brazil
17	NERICA-4 (Check)	Released variety in Ethiopia

Experimental designs and field management

Non-replicated single plots were used for observation experiments, while simple lattice and randomized complete blocks were employed for PVT and NVT, respectively. For VVT, single 10mx10m plots were used; and it was replicated 2-3 on-farm and on-station sites in Fogera, Pawe, Metema, Mytsebri and Assosa. Single row plots were used for observations, while 3 rows of plot size 3.75m2 for upland and high elevation PVS and 2.25m2 for upland PVT were used. Six rows of 7.5m2 plot was used for both NVTs. Seeds were drilled in a 0.25m spaced rows with a seed rate of 60 kg ha^{-1}. UREA and DAP fertilizers were applied with a rate of 100 kg ha^{-1} for each location. UREA was applied in splits while DAP applied all at planting. Two to three times hand weeding and other agronomic and plant protection management practices were applied uniformly across the plots for the duration of the experiment.

Table 6.Combined mean grain yield and other yield related parameters of 11 upland and high elevation rice genotypes in North West Ethiopia during 2017 and 2018

Genotype code	Genotype designation	DH	DM	PL	PH	GY tha^{-1}
1	ART15-16-31-2-1-1-1-B-1-1	77.03	121.30	20.84	89.51	3.84
2	ART16 5-10-22-4-B-1-B-B-1	76.53	119.73	19.79	90.30	4.04
3	Fogera 1 (Check 1)	77.20	121.60	21.01	90.61	4.22
4	ART16 9-29-10-2-B-1-B-B-1	77.27	122.27	20.15	88.35	3.66
5	ART16-4-13-1-2-1-1-B-1-1	77.10	120.40	20.33	89.65	3.42
6	ART16-9-5-28-3-13-1-B-2-1	77.80	120.83	20.38	90.72	3.45
7	ART16-9-9-25-2-1-1-B-2-1	77.20	122.00	19.25	86.52	3.42
8	ART16-9-19-11-2-2-2-B-1-2	78.4	122.20	20.55	94.95	3.06
9	ART16-9-25-30-3-2-2-B-1-1	78.03	121.47	19.82	93.87	3.71
10	ART16-12-28-32-3-B-1-1-2	77.50	120.53	20.65	89.80	4.02
11	NERICA-4 (Check 2)	77.77	119.93	20.86	90.41	3.69
	Mean	**77.26**	**121.11**	**20.33**	**90.43**	**3.68**
	CV (%)	**4.35**	**2.17**	**4.92**	**5.61**	**20.60**
	LSD (5 %)	**1.71**	**1.34**	**0.51**	**2.58**	**0.40**
	Genotype (G)	**NS**	***	***	***	***
	Location (L)	***	***	***	***	***
	GxL	**NS**	***	**	**NS**	***

Note: *, **, and *** refers to significant at 5%, 1% and 0.1% levels, respectively; NS=non -significant, 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 tha^{-1}= grain yield in tons per hectare

Table 7. Combined mean grain yield and other yield related traits of 17 upland rice genotypes in North West Ethiopia (five locations over two years)

Genotype code	Genotype designation	DH	DM	PL	PH	FTP	FGP	GY tha^{-1}	LB	PB	BS
1	NM1-29-4-B-P-80-8	75.58	110.60	20.12	85.4	5.08	117.93	3.99	1.1	1.8	0
2	ART16-9-29-12-1-1-2-B-1-1	76.38	111.40	20.06	92.27	5.5	105.58	3.53	1	0	0
3	ART16-9-14-16-2-2-1-B-1-2	74.37	110.00	20.93	86.78	5.1	107.93	3.89	1	0	1
4	ART16-9-33-2-1-1-1-B-1-2	81.20	114.00	20.19	92.12	5.3	118.75	4.40	0	1.1	0
5	ART16-9-122-33-2-1-1-B-1-1	79.18	111.00	19.82	90.52	5.3	105.58	4.22	0	1.1	0
6	ART15-19-5-4-1-1-1-B-1-1	79.23	112.20	20.49	89.83	4.95	101.75	3.93	1.2	0	1
7	ART16-5-9-22-2-1-1-B-1-2	80.13	113.60	19.52	91.58	5.3	119.03	4.44	0	1.2	1.1
8	ART16-21-4-7-2-2-2-B-2-2	76.58	111.20	19.95	86.52	5.43	111.58	4.09	0	1.0	0
9	ART16-9-16-21-1-2-1-B-1-1	79.80	112.90	20.62	91.33	5.68	113.88	3.99	1.6	1.2	0
10	ART15-13-2-2-2-1-1-B-1-2	76.60	109.30	20.83	86.64	5.42	102.5	3.43	1.7	1.1	0
11	ART15-16-45-1-B-1-1-B-1-2	77.00	110.70	19.92	86.84	4.98	110.93	3.71	0	0	1.1
12	ART16-5-10-2-3-B-1-B-1-1	78.48	111.40	21.32	92.06	5.18	117.28	4.11	1.	1.1	1
13	ART16-4-1-21-2-B-2-B-1-2	78.43	113.10	20.39	92.1	4.93	117.5	3.96	0	1.1	1
14	PARC.DAT.V-1.2013	83.70	114.80	21.14	87.8	5.6	108.5	3.84	0	1.3	0
15	PARC.DAT.V-2.2013	84.85	115.30	21.20	90.53	5.53	107.68	3.72	0	1.7	0
16	PARC.DAT.V-3.2013	84.20	115.20	20.87	89.62	5.42	109.58	3.71	0	1.2	0
17	NERICA-4(Check)	75.75	110.40	19.90	86.38	5.8	109.9	4.01	0	1.2	0
	Mean	**78.92**	**112.16**	**20.42**	**89.31**	**5.20**	**110.90**	**3.94**			
	CV (%)	**2.8**	**2.5**	**8.0**	**11.1**	**23.0**	**15.0**	**19.5**			
	LSD (5%)	**0.98**	**1.24**	**0.72**	**4.36**	**0.54**	**7.30**	**337.66**			
	Genotype (G)	***	***	***	**	*	***	***			
	Environment (E)	***	***	***	**	***	***	***			
	GxE	***	***	**NS**	**NS**	**NS**	*	**			

Note: *, **, and *** refers to significant at 5%, 1% and 0.1% levels, NS=non -significant, 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 tha^{-1}= grain yield in tons per hectare, LB=leaf blast, PB=Panicle blast, BS=Brown spot

Table 8. Mean grain yield of 17 upland rice genotypes across five environments in Northwest Ethiopia

No	Genotype	Assosa 2016	Assosa 2017	Fogera 2016	Fogera 2017	Gondar 2016	Gondar 2017	Pawe 2016	Pawe 2017	Shire 2016	Shire 2017
1	NM1-29-4-B-P-80-8	6598.0	3895.9	1770.9	2732.5	2980.0	6085.3	4090.0	4723.8	3593.8	3456.8
2	ART16-9-29-12-1-1-2-B-1-1	5237.0	4415.4	1540.0	2519.1	2775.9	4853.9	3865.8	3404.5	3750.0	2934.6
3	ART16-9-14-16-2-2-1-B-1-2	6516.0	2577.1	1545.7	2233.1	2634.5	5375.9	4437.8	5742.3	4425.0	3403.5
4	ART16-9-33-2-1-1-1-B-1-2	6762.0	5028.5	1495.5	3828.8	2807.9	5575.2	5119.9	5693.2	3643.8	4035.1
5	ART16-9-122-33-2-1-1-B-1-1	6754.0	3988.0	1637.5	3581.8	3182.6	5960.0	4176.4	5363.8	3862.5	3752.3
6	ART15-19-5-4-1-1-1-B-1-1	6008.0	3824.2	1238.3	3228.4	2543.5	5341.7	3859.6	5468.6	4409.3	3395.7
7	ART16-5-9-22-2-1-1-B-1-2	6346.0	4840.6	1462.4	4143.7	2946.5	5533.4	4154.7	7035.9	3762.5	4166.8
8	ART16-21-4-7-2-2-2-B-2-2	6454.0	3904.5	1648.7	3726.2	2831.9	5879.5	3763.1	5377.3	4050.0	3318.1
9	ART16-9-16-21-1-2-1-B-1-1	4784.0	4525.5	1344.4	3430.2	2840.2	5482.3	4222.7	6067.5	3806.3	3419.1
10	ART15-13-2-2-2-1-1-B-1-2	5404.0	3840.6	1198.0	2949.0	2227.5	4651.2	2998.0	3953.9	3675.0	3363.6
11	ART15-16-45-1-B-1-1-B-1-2	5509.0	4127.0	1216.8	2399.0	2553.4	5292.3	4655.9	4420.8	3943.8	3032.2
12	ART16-5-10-2-3-B-1-B-1-1	5990.0	5410.8	1497.3	3496.1	2631.2	4649.6	4278.3	6123.9	3468.8	3587.4
13	ART16-4-1-21-2-B-2-B-1-2	6476.0	4976.4	1522.2	3463.8	2474.7	5056.4	3490.9	5525.9	3312.5	3345.0
14	PARC.DAT.V-1.2013	6959.0	3526.2	1157.3	2053.1	2968.0	5171.5	4094.2	5374.2	3881.3	3246.0
15	PARC.DAT.V-2.2013	6507.0	3524.6	1802.3	2326.5	2755.9	4688.7	3637.5	5439.7	3400.0	3097.4
16	PARC.DAT.V-3.2013	4444.0	3808.1	1082.5	2299.2	2922.0	5187.9	3980.0	6719.9	3593.8	3112.1
17	NERICA-4(Check)	5744.0	4099.6	1791.2	3593.2	2670.2	6125.8	3818.9	5320.8	3700.0	3211.5
	Mean	**6028.9**	**4136.1**	**1467.7**	**3059.0**	**2749.8**	**5347.7**	**4037.9**	**5397.4**	**3781.1**	**3404.5**
	CV (%)	**23.5**	**20.0**	**27.9**	**15.3**	**13.6**	**12.4**	**17.8**	**18.8**	**13.8**	**10.0**
	LSD (5 %)	**2010.7**	**1176.6**	**583.6**	**667.2**	**532.06**	**945.63**	**1022.3**	**1442.4**	**742.5**	**505.7**

Table 9. Morphological and agronomic description of the newly released rice variety, Azmera

Parameter	Description
Variety type	**Upland**
Variety name	**Azmera (ART16-5-9-22-2-1-1-B-1-2)**
Agronomic and morphological characteristics	
Adaptation area	Fogera, Assosa, Pawe, Gondar, Maitsebri
Altitude (masl)	750-1860
Rain fall(mm)	100-1457
Seed rate(kg/ha)	60
Planting date	Early June to late June depending on the onset of rainfall
Spacing (cm)	25 cm between rows for row drill planting
Fertilizer rate (kg/ha) and time of application	N= 69 (1/3 at planting, 1/3 at tillering and 1/3 at panicle initiation) P_2O_5= 23 (all at planting)
Days to heading	80
Days to maturity	114
Panicle length(cm)	19.5
Plant height (cm)	91.6
Thresh ability	Fair
Lodging incidence	None
Shattering	Resistant
Seed size (mm)	Slender shape [length (6.8): width (1.8) =3.8]
Growth habit	Erect
No. of grains per panicle	119
Caryopsis color	White
Crop pest reaction	Moderately resistant to major rice diseases
Grain yield(kg/ha)	
Research field	4800
Farmers field	4600
Year of release	2019
Breeder/maintainer	Fogera National Rice Research and Training Center/EIAR

Data collection and analysis

At the early stage of evaluation, the main parameters considered were, disease and insect pest freeness, earliness, phenotypic acceptability and uniformity, and some agronomic traits. At the PVT and NVT evaluation stages, data were recorded on phenological and agronomic traits including grain yield. Measurements on all parameters were taken on central rows. Grain yield and thousand seed weight data were adjusted to14% grain moisture content. Selection and promotion of genotypes were mainly based on high grain yield augmented with high biomass and quality parameters such as white caryopsis color and larger grain size. SAS software v. 9.3 was employed to analyze the data. Single site analysis was performed for PVTs, while multi-environment analysis for the NVTs. For the VVT, decision was made by the National Variety Releasing Committee based on VVT site visits of the technical team and performance and stability data submitted by breeders.

RESULTS AND DISCUSSION

Quarantine and observation nurseries

There was no quarantine pests found in both observation nurseries. For the upland and high elevation set, seventy genotypes out of one hundred, two, which were disease and insect pest free, early, with phenotypic acceptability and uniformity have been promoted to PVT (Table 2). Thirty-two out of the 34 genotypes were promoted to the PVT for the upland set (Table 3).

Preliminary variety trails (PVTs)

Single site analysis for grain yield and other agronomic traits of the upland and high elevation set showed that only 9 genotypes were showed comparable performance to the check (Nerica-4) and hence promoted to the NVT (Table 4) for further evaluation. Some of the 9 genotypes performed close to 5tons per hectare grain yield. Those genotypes were also good for other agronomic traits such as earliness, large panicle size, tall in plant height, large number of fertile tillers and filled grains. For the upland set, sixteen genotypes outsmarted the check mainly for grain yield and other agronomic traits and hence promoted to NVT. The lists of the sixteen genotypes are provided in Table 5. The grain yield performance of some of these genotypes reached close to 6 tons per hectare.

National variety trails (NVTs)

For the upland and high elevation set, combined ANOVA depicted that none of the 9 test genotypes were performed significantly superior than the recently released check variety, Fogera 1 (Table 6). Two test genotypes (Geno 2 and Geno 10) showed superior performance in grain yield than the other check, Nerica-4. Nevertheless, there was no variety verification trail composed from this set. This is because the test genotypes didn’t outsmart the recently released variety, Fogera -1; and the genetic gain should be calculated compared to Fogera-1. Although none of the test genotypes were proposed to be verified, some of the test genotypes showed good portfolios such as for plant height and comparable grain yield performances (Table 6). On the other hand, genotype by environment interaction (G x E) was found to be significant and important source of variation and needs to be exploited (Ebdon and Gauch, 2002). In this regard, test genotype 10 (6.5 tha-1) showed superior performance than any of the two checks in Pawe and Asssosa and hence specific adaption of these varieties could be targeted and exploited. Similar results of significant G x E in Ethiopia have been documented by various researchers (Atnaf et al., 2019; Dessie et al., 2020; Lakew et al., 2017; Tariku, 2017). Combined mean grain yield and other yield related parameters of 11 upland and high elevation rice genotypes in North West Ethiopia during 2017 and 2018 (Table 6).

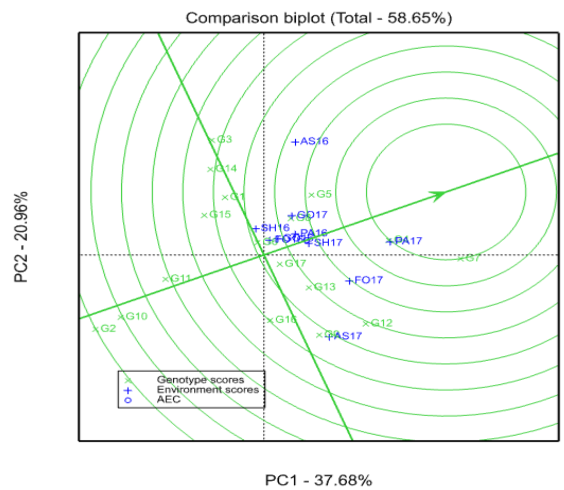

Figure 1. Average-environment coordinates (AEC) view showing ranking of genotypes relative to an ideal genotype (Center of the concentric circle).

Combined analysis of variance for the upland set showed that there exists variability among the test genotypes for grain yield and other agronomic traits (Table 7). The next research question to be answered with this study was, whether there were test genotypes which are significantly superior to the standard check? It was found that two test genotypes (ART16-5-9-22-2-1-1-B-1-2 and ART16-9-33-2-1-1-1-B-1-2) outperformed the standard check in terms of grain yield, earliness, and larger grain size. The result further depicted that genotype by environment interaction was an important source of variation in the current data structures (Table 7). This is in line with previous reports documented on rice (Atnaf et al., 2019; Bose et al., 2012; Dessie et al., 2020; Wasan et al., 2018). The present result advises us that apart from over all mean performance, we need also consider stability of the test genotypes as additional criteria of selection. In this regards, those two test genotypes (ART16-5-9-22-2-1-1-B-1-2 and ART16-9-33-2-1-1-1-B-1-2) also showed good stability; and hence combined high performance and stability across environments (Table 8; Fig 1). Such genotypes are regarded as desirable ones for producers as they offer both high yield and consistent performance across growing environments. Hence, these two candidate genotypes were composed into a variety verification trail to be verified and released.

Variety verification trail (VVT)

The candidate with designation, ART16-5-9-22-2-1-1-B-1-2 was accepted and approved by the national variety releasing committee. This candidate performed more than 10% yield advantage compared to the standard check. It also had white caryopsis color and extra-long grain size, which could make the candidate suitable to the users and market preference (Table 7). This variety is named as 'Azmera' for ease of communication along the value chain actors. Profile of Azmera is provided on Table 9.

CONCLUSION

The objective of developing desirable upland rice variety was successful; and Azmera was identified as desirable variety, which showed high and stable performance. It is a variety, which is profiled with high grain yield, earliness, larger grain size and white caryopsis. Azmera showed more than 10% yield advantage over the standard check. It is recommended to be produced in lower altitude and high temperature rice producing areas such as Pawe, Assosa, Metema and similar agro-ecologies. On the other hand, no desirable variety was identified for the high elevation upland ecology.

AUTHOR CONTRIBUTIONS

Abebaw Dessie and Taddesse Lakew set-up the experiments; Abebaw Dessie, Zelalem Zewdu, Asaye Berie, Mulugeta Bitew and Zeynu Tahir carried out the experiments in their respective locations. Mulugeta Atnaf and Abebaw Dessie analyzed the data and developed the manuscript. Fisseha Worede contributed in data analysis and manuscript review.

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COMPETING INTERESTS

The authors declare that they have no competing interest

ETHICS APPROVAL

Not applicable

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