Application for release and registration of four aromatic rice (*Oryza sativa* L.) varieties targeting rainfed lowland areas

By

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Submitted to

The National variety release committee (NVRC)

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Table 1 Research Team and Roles

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Dr. Otim Michael	Entomologist	Insect Pests studies
Dr. Alibu Simon	Agronomist	Agronomic studies
Ms. Adur Stella Everline	Socio-Economist	Socioeconomic studies
Mr. Kwemoi Daniel Bomet	Plant Breeder	Field trials designing
Dr. Serrumaga P Julius	Molecular Biologist/Pathologist	Statistical analyses and reporting
Dr. Abubaker Muwonge	Molecular Biologist	Data Analysis/Molecular studies
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Mr. Ekebu James	Technician	General Data collection
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Dr. Asea Godfrey	Director of Research	General Project Supervision

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1.0 IMPORTANCE OF RICE IN UGANDA

Rice (*Oryza sativa*. (L) is an important staple food and commercial crop in Uganda grown on 77,393 ha providing 220,000 MT, occupying 1.12% of arable land of Uganda, annually (FAOSTAT, 2020). This production level reflects an import substitution value of USD 88.0 million. However, the country still imports an average of 78,000 MT of rice leading to direct loss of foreign currency of USD 35.1 million, annually. Despite this demand gap Uganda also exports rice. For instance, in 2017 Uganda exported 27,085 tonnes of rice to the Democratic Republic of Congo, 15,009 tonnes to South Sudan, 2,270 tonnes to Kenya and 964 tonnes to Rwanda (Kilimo Trust, 2018). This is an estimated exports value of USD 26.96 million based on international market price.

Uganda along with other East African countries imports three rice types of specific qualities considered premium. The first are aromatic (pop-corn aroma), slender and long grain varieties called the basmati-type. The second are aromatic (fruity aroma), slender and long grain varieties called the Jasmine-type. The third are non-aromatic and medium grain called Pakistan or Vietnam rice. In order to compete favorably with the imported rice, varieties with similar or better qualities are needed.

Rice types produced in Uganda two, the aromatic and non-aromatic rice, popularly called 'Kaiso' rice. Most consumers, prefer aromatic, non-sticky, whole grain and white rice grains traits Uganda Masette et al. (2013), with up to 65% of urban rice consumers preferring aromatic rice while yet only 29% can access it. Similarly, although 60% of the rural population desire fragrant/aromatic rice, only 39% consume it. Akongo et al. (2017) reported that Uganda's locally produced 'SUPA rice' is the most preferred for its taste and aroma and thus the most consumed in Kampala. This was followed by 'Kaiso' because of its cooking property of expanding in quantity when cooked [26] due to the swelling of the starch granules caused by the high temperatures during cooking [40]. Kaiso is a collection of rice varieties which expands upon, medium grain in size and non-aromatic. Kaiso now include irrigated varieties K5, K23, K64, K85, K264 and upland varieties NamChe1-6 and WITA-9, most of which is sold as commingled rice.

All rice varieties grown in Uganda are adapted to irrigated or upland production conditions, except SUPA that is adapted to rainfed lowland production conditions. SUPA is aromatic but susceptible to RYMV, rice blast disease that are very devastating in Uganda. An improved rice variety with moderate aroma characteristics, shorter maturity period and moderately resistant to diseases called KOMBOKA was released in the country in 2014 for irrigated rice production but is not adapted to rainfed lowland production areas. Rainfed lowland rice contributes up to 40% of total rice produced annually in Uganda but covers only 20% of the total area under rice production. The rainfed lowland production areas have a very high potential for production in the country because higher yields and double production can be achieved in this production areas

(Lamo et al 2017, Lamo et al 2005). However, no rainfed lowland rice varieties have been released in the country.

2.0 RATIONALE AND BREEDING HISTORY FOR 4 CANDIDATE VARIETIES

2.1 Rationale for variety development

Uganda rice consumers have a strong preference for aromatic rice (Masette, 2013). In response to this demand, farmers continue to produce rice variety SUPA V88 that has desirable aroma characteristic and grain qualities but its production is limited by low yield, late maturity and susceptibility to major diseases under rainfed lowland conditions. For this reason, there is high importation of aromatic rice variety "Basmati" to address this demand and supply gap. SUPA is known for its high aroma characteristic and large grain size.

Since 2015, the breeding program at National Crops Resources Research Institute (NaCRRI) focused on development of new rice types using various breeding approaches. Here, we present 4 candidate inbred rice varieties targeting rainfed lowland production areas with grain characteristics of SUPA and three other varieties with characteristics of Basmati.

2.2 Variety origin and development

PR 107:

i Original Designation: PR 107

ii Cross (parents): DR449 (♀) × MP3-235 (♂)

Parent : DR449 with the full name DianRui449, was an elite rice variety with high eating quality in Yunnan, China.

Parent 2: MP3-235 was the perenniality donor selected from the original cross *RD23* (♀) × *O. longistaminata* (♂)MP3-235 was developed as a perenniality donor line through wide hybridization of annual Oryza sativa RD23 and perennial *Oryza longistaminata*. The *O. longistaminata has* high tolerance to most biotic and abiotic stresses.

Line PR 107 was bred as new rice type perennial rice through hybridization between a good eating elite variety DR449 and perenniality donor MP3-235, followed by marker assisted selection (MAS). New line PR107 generated having special attributes that include high yield, high ratooning ability and tolerance to stresses. The development was through collaborative research between NARO and Yunnan University, Kunming, China.

iii Selection History: Fixed and segregating lines were selected through collaborative staff attachment at Yunnan University.

iv Country of origin: Recombined at Yunnan, China

PR 107 have been introduced to replace the popular cultivar SUPA, that is not widely cultivated in the country due to susceptibility of foliar diseases (RYMV, blast and brown spot) and yet has high preference by the consumers.

Rainfed lowland rice farmers in northern, mid-western and eastern Uganda (where rainfed lowland is primarily grown) grow two crops annually and needed a replacement for SUPA with a variety which is early maturing (<120 d), aromatic, with more robust RYMV resistance and higher ratooning ability.

Selection was performed for panicle yield, plot yield, maturity, panicles per unit area, 1000 grain weight, grain shape, and diseases (RYMV, brown spot and blast) resistance.

MET 12 and MET 20:

ii Original Designation: MET 12 and MET 20, respectively

ii Cross (parents): IRGC 104084 (♀) × TGS 25 (♂)
Parent 1: IRGC 104084 (♀) was sourced from AfricaRice genebank. It was developed earlier for early maturity, seed size, aroma, drought tolerance, and resistance to diseases
Parent 2: TGS 25 (♂) was sourced from AfricaRice genebank. It is one *O. barthii* collections at AfricaRice. *O. barthii* has long panicles, diverse grain sizes and weight which might be considered a prerequisite for high yield; the long flag leaf and awns may both offer protection against bird damage. AfricaRice (2012) reported that the flag leaf shields the panicles from the sight of flying birds while the long awns could make access to the grains difficult. *O. barthii* hosts a lot of diversity that is not available in *O. glaberrima* (Orjuela et al., 2014).

iii Selection History: F3 populations shared under AfricaRice Task Forces shuttle breeding arrangement

iv Country of origin: Recombined at AfricaRice, Nigeria

v Source of materials (Breeding Nursery Trial 2017) comprising 100 lines of F4 generation.

These candidate lines were therefore developed through interspecific crossing by AfricaRice and NARS partners

MET 12 and MET 20 have been introduced to replace the popular cultivar Basmati, that is not widely cultivated in the country due to susceptibility to foliar diseases (RYMV, blast and brown spot) but about 30,000-40,000 MT is imported annually. This importation causes the country USD13.5-18.0 mill per annum.

Selection was performed for panicle yield, plot yield, maturity, panicles per unit area, 1000 grain weight, grain shape, and disease (RYMV, brown spot and blast) resistance. The two lines have been presented as preferred slender grain, aromatic and RYMV, blast and brown spot resistant cultivar.

ARU 1189:

- i Original Designation: ARU 1189
- ii Cross (parents): PSBRC 68 (*Oryza sativa*) with CG14 (*Oryza glaberrima*).
- iii Selection History: Shuttle breeding populations
- iv Country of origin: Recombined at AfricaRice, Nigeria
- v Source of materials (Breeding Nursery Trial 2017) comprising 2000 lines of F3 generation

Developed through shuttle breeding by crossing PSBRC 68 (*Oryza sativa*) with CG14 (*Oryza glaberrima*). Selection was performed for panicle yield, plot yield, maturity, panicles per unit area, 1000 weight, grain shape, and RYMV, brown spot and blast resistance.

Rainfed lowland rice farmers in northern, mid-western and eastern Uganda (where rainfed lowland is primarily grown) grow WITA-9 which was released for irrigated conditions and yield potential is not realized due to less tolerance to seedling stage submergence when direct seeded and susceptibility to drought stress in the rainfed lowland production areas which ARU 1189 has tolerance to. Subsequently, ARU 1189 has been presented as another variety along with WITA-9 as the preferred equally early maturing (<120 d), drought tolerant, tolerant to seedling stage submergence, and RYMV and blast resistant cultivar.

Candidate Cultivar description

Details of standard morphological descriptors following the [International Rice Research Institute (IRRI), Africa Rice and International Board for Plant Genetic Resources (IPBGR)] for the lines are presented in Table 19

3.0 METHODOLOGY

3.1 Genetic material

The candidate rice varieties were selected from a trial set of 11 rice genotypes that were found to be promising in advanced evaluation in an earlier study (Table 2).

Table 2 Summary of development of candidate lines

	Genotype	Pedigree	Parental lines	Rice group	Status	Source
1	AGRA 55	AGRA-CRI-UPL-4-4	NERICA-4/JASMINE	*O.sativa/O.glaberima//O.sativa*	Breeding line	ACRI-Ghana
2	AGRA 78	AGRA-CRI-UPL-4-4	NERICA-4/JASMINE	*O.sativa/O.glaberima//O.sativa*	Breeding line	ACRI-Ghana
3	ARU 1189	IR77454-22-B-20-2-2-B-TGR1	PSBRC 68/CG14	*O.sativa/O.glaberima*	Breeding line	NARO-AfricaRice
4	IR 1052	NM-16-25-16-1-1-1-	SUPA V88/NERICA-L19	*O.sativa//O.glaberima/O.sativa*	Breeding line	IRRI-ESA
5	KOMBOKA	IR 05N221	IR 74052-297-2-1/IR 71700-247-1-1-2	*O.sativa/O.sativa*	Released	IRRI-ESA
6	MET 12	ART ART34-88-1-2-B-1	IRGC 104084/TGS 25	*O.barthi//O.glaberima/O.sativa*	Breeding line	NARO-AfricaRice
7	MET 16	ART27-58-7-2-2-3	IRGC 104084/TGS 25	*O.barthi//O.glaberima/O.sativa*	Breeding line	NARO-AfricaRice
8	MET 20	ART35-272-1-2-B-P1	IRGC 104084/TGS 25	*O.barthi//O.glaberima/O.sativa*	Breeding line	NARO-AfricaRice
9	PR 107	NA	RD23/TGS 115 (*Oryza longistaminata*)	*O.sativa/O.longistaminata*	Breeding line	China
10	TXD 306	SARO-5	*Supa/Pyongyang8* × *Subarimati/Supa*	*Supa/Pyongyang8* × *Subarimati/Supa*	Breeding line	Tanzania
11	WITA-9	WITA-9	IR 2042-178-1/CT19	*O.sativa/O.sativa*	Released	AfricaRice

3.2 Experimental sites

Evaluation was conducted in six sites representing the major lowland rice production areas in Uganda. These sites were selectively chosen as hotspots for screening for major diseases, drought and submergence tolerance (Table 3). Two major activities were conducted between 2017 and 2021 that resulted in the selection of the 4 candidates herewith submitted for release. First was on-farm screening and evaluation of introductions. In the second activity, both on-station and on-farm performance tests were conducted.

Table 3 Experimental sites

Site	Location name	Latitude	Longitude	Trait important in the location	Elevation (masl)	Region
1	WAKISO	0.528667	32.626306	RYMV, Blast, BLS	1114	Central
2	OYAM	2.460528	32.236111	Blast	1110	North
3	KASESE	0.239667	30.122694	RYMV, Blast	1057	West
4	BUGIRI	0.530056	33.878944	RYMV, Blast, BLS	1076	East
5	LIRA	2.184417	33.032417	RYMV, AfRGM,	1061	Mid North
6	SOROTI	1.864417	33.478944	AfRGM	1073	East
7	ALEBTONG	2.256139	33.415861	RYMV, Blast	1058	Mid North
8	GULU	2.838583	32.286917	Blast	1057	North
9	NWOYA	2.617806	32.053333	Blast	982	North
10	PAKWACH	2.267278	31.312583	Submergence	652	North West
11	BUTALEJA	0.85575	33.937917	RYMV, Blast, BLS	1066	East

3.3 On-station diseases screening, seed increase and evaluation

The 9 candidate lines and another 21 rice genotypes were screened for RYMV at NaCRRI. These included, IR 64 (susceptible control), Gigante (AfricaRice resistant check), NamChe-2 (local resistant check).

Virus isolates earlier collected from Central Uganda, within the rice fields at Namulonge, were used in this study. This was part of NARO plant virus collection maintained at the Bioscience Laboratory, at NaCRRI. Isolate UGB1 used in this study was the most virulent in our collections.

The virus isolates were first propagated in susceptible rice variety IR64. When the leaves showed clear visible symptoms, they were harvested two weeks post-inoculation, and used as inoculum source. The infected leaf samples were ground with sterile pestles and mortars in 0.05 M potassium phosphate buffer, pH 7.0 at the ratio of 1g of leaf for 10 ml of buffer. The extract was subsequently rubbed onto the leaves of rice test seedlings 21 days post-germination (DPG). An inoculation test plant was done using mechanical method in an insect-proof rain-out shelter at 25 to 30°C and 80 to 90% relative humidity. Development of disease symptom was monitored for 45 days post-inoculation (DPI). A 1-9 quantitative scale was used is described as follows: 1= No symptom observed; 3 = Leaves green but with sparse dots or streaks and less than 5% of height reduction; 5= Leaves green or pale green with mottling and 6% to 25% of height reduction, flowering slightly delayed; 7= Leaves pale yellow or yellow and 26-75% of height reduction, flowering delayed; 9= leaves turn yellow or orange, more than 75% of height reduction, no flowering or some plants dead.

3.4 Field performance evaluations

Replicated trials for yield and grain characteristics were performed for 3 yrs (2018–2020, representing five growing seasons at four or more on-farm National Performance Trial (NPT) locations (WAKISO, OYAM, KASESE, BUGIRI, BUTALEJA, SOROTI, ALEBTONG, LIRA, GULU, NWOYA and PAKWACH) under rainfed conditions. The design was a randomized complete block with 3 replicates in 2m x 5m plot sizes. Planting method was line dibbling at spacing of 20 cm and seed rate 3 seeds per hill. This was achieved by thinning to three plants per hill at 15-17 days after germination.

Twenty-six trials were planted with the onset of rains. The first trials were conducted in the second cropping season of 2017 (2017B); planting was done in June 2017 at three NPT locations (WAKISO, BUTALEJA and LIRA). Trials were repeated in the first cropping season of 2018 (2018A), planted in March 2018 at 11 NPT locations (WAKISO, OYAM, KASESE, BUGIRI, BUTALEJA, SOROTI, ALEBTONG, LIRA, GULU, NWOYA and PAKWACH). Season 3 trials were planted in 2018 (2018B), planted in July 2019 at 11 NPT locations (WAKISO, OYAM, KASESE, BUGIRI, BUTALEJA, SOROTI, ALEBTONG, LIRA, GULU, NWOYA and PAKWACH). Season 4 trials (2020A) were planted in March 2020 at one NPT locations (WAKISO). No fertilizer or fungicides were applied in any of the locations. Representative data could not be collected from 4 locations due to premature drying of the crop due to drought.

In the trial sites, joint evaluation was done with researchers, farmers and extension agents. Farmers' views for selection of varieties included maturity time, grain size, panicle length and the overall yield. The trial was conducted in the second season 2018 and first season of 2019. Data were collected on Days to 50% (DDF), maturity time (MATD), Plant height (PH), productive Tiller number, Blast score, Bacterial leaf blight (BLB), bacterial leaf streak (BLS), Brown leaf spot (spot), Rice Yellow Mottle Virus disease score and yield estimates.

3.5 Statistical analysis

Analysis of variance and mean performance

Data for each variable were analyzed using the PROC ANOVA procedure in SAS 9.4 (SAS Institute, 2012). Before running separate analyses by year, a Bartlett test of homogeneity of variance test was conducted. The biological explanation for the separate analysis by year was also provided by different edaphic and environmental factors. Within each year, location, and location × variety interaction were used as random factors, and appropriate error terms were used to calculate the mean sum of squares of each variable factor. If the F value was significant, a mean separation test was conducted using the LSMEANS procedure in SAS. In the LSMEANS procedure, additional PDIFF and PDMIX 800 options were used to evaluate the probability significance among various main and interaction effects. Means were considered statistically different if the p value was ≤.05.

GEI and stability analyses

AMMI analysis was performed on yield to determine the contribution of the genotypes, environments, as well as their interaction to the total variation and stability test conducted.

GGE-Biplot showing the most ideal varieties was generated using Gentat VSN international, version 16.

3.6 Results and Discussions

Response of 21 lines to foliar diseases

All the test lines except control NamChe-2, MET 12 and MET20 showed symptoms of RYMV. The reactions of rice accessions to the RYMV isolates are summarized in Table 3. Days to symptom appearance varied among the accessions inoculated with the disease inoculum. Symptoms on the leaves of the susceptible control IR 64 were observed at 9 DPI. Lines with scores 1 and 3 were selected for further advance (Table 4). Of the 21 lines, 16 showed score of 5 and lower

Results of analysis for genetic variation and trait heritability among candidates show that there was significant genetic variance among test genotypes with lowest CV being 2.55 and highest 323.4 (Table 5). High heritability values was also observed among genotypes in individual sites and across sites (Table 5).

Table 4 No of days to symptom appearance of RYMV and susceptibility score

No.	Genotype	Source	Symptom DPI	RYMV severity
1	K 98	Landrace	18	5
2	AGRA 55	CRI-Ghana line	18	3
3	AGRA 78	CRI-Ghana line	12	3
4	ARU 1189	NARO-AfricaRice	16	3
5	IR 1052	NARO-IRRI	16	3
6	KOMBOKA	IRRI	14	5
7	MET 12	NARO-AfricaRice	18	1
8	MET 16	NARO-AfricaRice	11	3
9	MET 20	NARO-AfricaRice	12	1
10	PR 107	NARO-Yunnan University	17	3
11	TXD 306	Tanzania	16	3
12	WITA-9	AfricaRice	15	5
13	BASMATI	IRRI	11	7
14	SUPA	landrace	10	5
15	MET 13	NARO-AfricaRice	12	5
16	MET 33	NARO-AfricaRice	16	7
17	IR 1027	NARO-IRRI	10	7
18	PR 26	NARO-Yunnan University	12	7
19	IR-64	IRRI Susceptible check	9	7
20	Gigante	AfricaRice Resi check	18	3
21	NamChe-2	Uganda Resi check	0	1
Mean			13.43	4.14
CV			8.3	4.1

Table 5 Genetic variation and trait heritability among candidates

Statistic	DDF	MATD	PltHt	Blast	BLB	BLS	SPOT	RYMV	Yield (T/ha)
Genotype Variance	216.62	212.06	266.15	0.51	0.19	0.02	0.40	0.28	0.58
Gen x Loc Variance	0.07	0.00	0.44	0.09	0.14	0.00	0.09	0.43	0.03
Location Variance	5.24	1.35	4.07	0.00	0.02	0.00	0.01	0.00	0.20
Residual Variance	6.19	19.66	15.90	0.40	0.26	0.05	0.57	0.59	0.11
Grand Mean	97.63	121.85	98.01	1.40	1.04	0.07	2.62	0.41	4.95
Heritability	**1.00**	**1.00**	**1.00**	**0.95**	**0.87**	**0.72**	**0.92**	**0.80**	**0.99**
LSD	2.09	1.72	2.22	0.38	0.41	0.15	0.43	0.62	0.37
CV	2.55	3.64	4.07	45.34	48.68	323.40	28.71	186.06	6.58
n Replicates	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
n Locations	11.00	11.00	11.00	8.00	8.00	3.00	8.00	9.00	11.00
Genotype significance	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

GenxLoc significance	0.58	1.00	0.24	0.00	0.00	1.00	0.00	0.00	0.00
Loc significance	0.00	0.00	0.00	1.00	0.10	1.00	0.63	1.00	0.00

The AMMI ANOVA (Table 6) showed significant effects of genotypes and environments as well as their interactions for yield. The effects of genotype and respective contribution to the treatment sum of squares was 69.70%. The effects of genotype, environment was highly significant ($p < 0.001$), and their respective contribution to the treatment sum of squares was 69.70 % and 23.8%. Genotype by environment interaction (GEI) contribution was low 6.45 % but highly significant ($p < 0.001$). In the present study, the greater contribution of genotypes (69.70%) relative to environment (23.8%) and GEI (6.45%) to the treatment sum of squares suggests the greater diversity in genotypes. This contrary to reports that environment usually explains 80% or more of the total variation in multi environment yield trials. The significant GEI would also suggest the existence of considerable differences among genotypes in their responses to varying environments.

Table 6 ANOVA Table for AMMI model

Source	d.f.	s.s.	m.s.	v.r.	F pr
Total	725	606419807	836441		
Treatments	241	562785093	2335208	33.26	<0.001
Genotypes	10	392270604	39227060	558.73	<0.001
Environments	21	134166780	6388894	22.06	<0.001
Block	44	12743174	289618	4.13	<0.001
Interactions	210	36347710	173084	2.47	<0.001
IPCA 1	30	12368645	412288	5.87	<0.001
IPCA 2	28	7893229	281901	4.02	<0.001
Residuals	152	16085836	105828	1.51	<0.001
Error	440	30891539	70208		

Analysis of variance was verified by using sums of squares (SS) for genotypes (G), GEI signal (GEIS) and GEI noise (GEIN). The GEIN is obtained by multiplying mean squares of error by the GEI degrees of freedom and then GEIS is obtained by subtracting from GEIN sum of squares. Accordingly, 70208 (error mean square) × 210 (GEI degrees of freedom) = 14743680 noise sum of squares (40.56% of GEI) and 36347710−14743680 = 21604030 signal sum of squares (59.44%). This showed that the AMMI analysis was appropriate because it fulfilled the minimum requirement that GEIS must be as large as G for the dataset. Here the GEIS less than G by a large margin of 30%.

Genotypes PR 107, MET 12 and MET 20 had low stability values, while TXD 306, AGRA 55 and WITA 9 were the most unstable (Table 7). The small ASV score for PR 107, MET 12 and MET 20 indicates a more stable genotype as well as less interactive environment.

Genotypes MET 20, MET 12, PR 107 and AGRA 78 have IPCA1 scores near zero indicating that they are less interactive compared to those far from zero namely TXD 306, AGRA 55, ARU 1189 and IR 1052, T. Similarly, genotypes with positive value have yields above mean yield, these are WITA 9, MET 20, PR 107 (Table 7).

Results of GGE-Biplot showed that MET12, ARU1189, PR107 are close to the center of concentric implying that they are the genotypes are the most stable across environments. Varieties AGRA 78 and TXD 306 are the most unstable across locations (Fig.1).

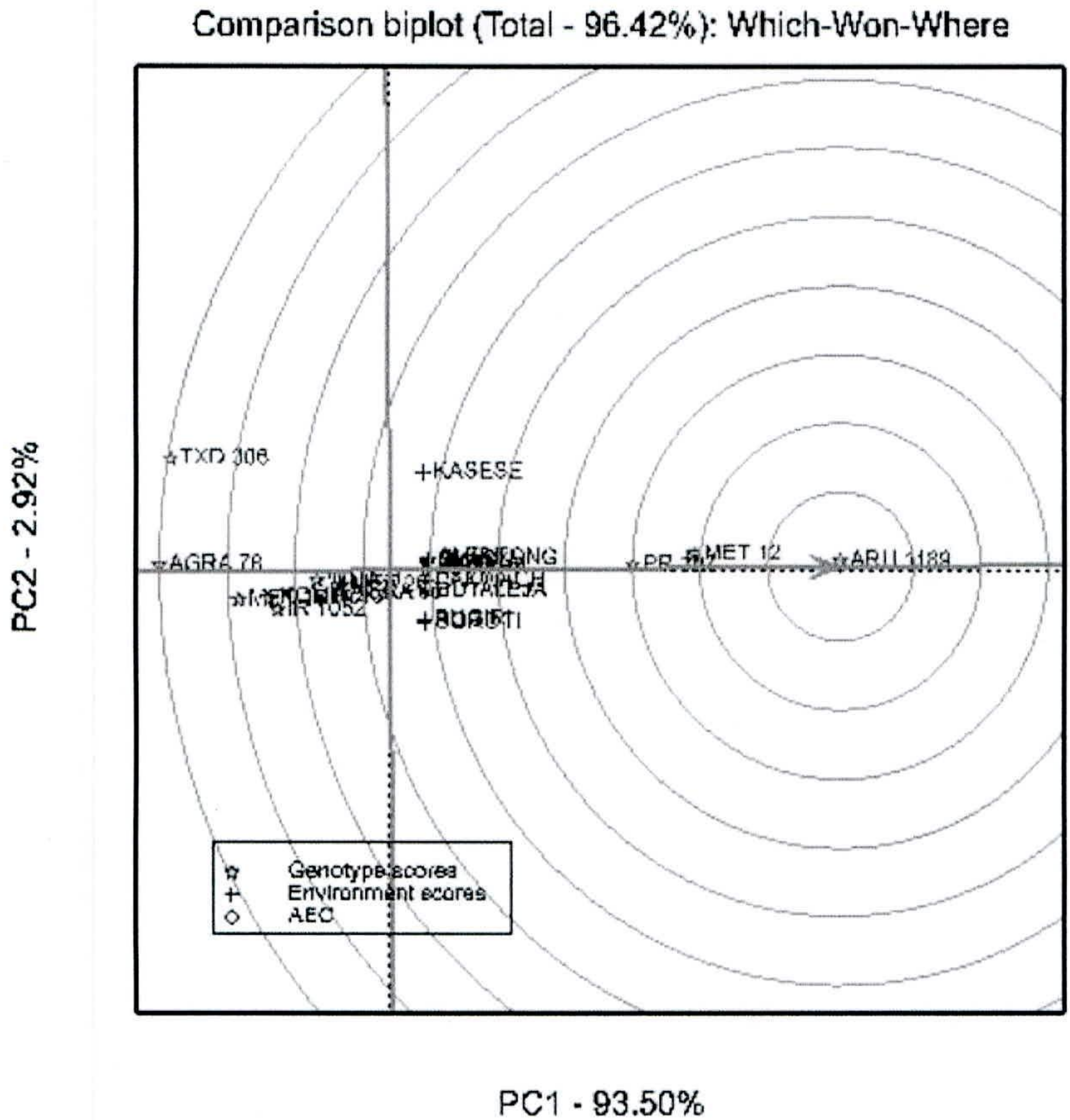

Figure 1 Showing the most stable genotypes across locations

Table 7: Genotype yield, stability parameters and yield advantage over control

No	Genotype	Yield	Rank	IPCAg1	IPCAg2	Stability (ASV)	ASV rank	Ysi	Yield and stability	% Yield over KOMBOKA	% Yield over WITA-9
1	AGRA 55	4861	4	11.73114	-13.65282	22.9	9	13	6	6.3	3
2	AGRA 78	4209	10	-5.76918	-13.57256	16.31	6	16	9	-7.9	-10.8
3	ARU 1189	6520	1	11.21404	-3.62533	17.94	8	9	3	42.6	38.1
4	IR 1052	4606	7	10.58324	2.77886	16.82	7	14	8	5	-2.4
5	KOMBOKA	4571	8	8.88695	-1.73478	14.03	5	13	6	0	-3.2
6	MET 12	5985	2	-1.27534	-7.83489	8.09	2	4	1	30.9	26.8
7	MET 16	4468	9	5.54047	0.57064	8.7	3	12	5	-2.3	-5.3
8	MET 20	4761	5	0.70354	10.35484	10.41	4	9	3	4.2	0.9
9	PR 107	5780	3	3.45111	3.09505	6.23	1	4	1	26.4	22.5
10	TXD 306	4187	11	-38.06759	-7.81196	60.16	11	22	11	-8.4	-11.3
11	WITA-9	4720	6	-6.99838	31.43296	33.29	10	16	9	3.3	0

Key: ASV: Average Stability Value
Ysi: Yield Stability Index

Environments ALEBTONG_1, GULU_1, GULU_2, LIRA_2, LIRA_2, NWOYA_1, OYAM_1, WAKISO_1 and WAKISO_1 had IPCA1 scores near zero indicating that they are less interactive compared to KASESE_1, KASESE_2 and SOROTI_2. Sites ALEBTONG_1, GULU_1, GULU_2, LIRA_2, LIRA_2, NWOYA_1, OYAM_1, WAKISO_1 and WAKISO_1 could be representative for evaluation of rice germplasm (Table 8).

Table 8 Environmental means, score and ranks

Environment	Number	Mean	RANK	IPCAe1	IPCAe2
ALEBTONG_1	1	4,753	20	-3.3757	2.30657
ALEBTONG_2	2	4,759	18	-5.40386	0.34917
BUGIRI_1	3	**5,640**	2	4.70251	2.96016
BUGIRI_2	4	**5,702**	1	15.902	-0.93496
BUTALEJA_1	5	5,105	8	-4.53268	22.18622
BUTALEJA_2	6	5,109	7	4.07279	4.7152
GULU_1	7	5,072	9	-1.45162	3.3645
GULU_2	8	4,955	13	0.18356	-2.98024
KASESE_1	9	3,858	22	-22.64538	-4.30975
KASESE_2	10	3,896	21	-23.27837	-4.505
LIRA_1	11	**5,177**	5	8.2414	-3.31705
LIRA_2	12	5,027	10	0.27026	2.84876
NWOYA_1	13	4,977	12	-3.43548	1.39956
NWOYA_2	14	5,013	11	4.96829	-2.8006
OYAM_1	15	4,921	14	-3.93854	4.2045
OYAM_2	16	4,880	16	-4.38843	-4.53452
PAKWACH_1	17	4,882	15	5.52038	-18.76252
PAKWACH_2	18	**5,156**	6	9.02265	-17.53676
SOROTI_1	19	**5,423**	3	10.67325	16.80653
SOROTI_2	20	**5,405**	4	15.33417	0.79684
WAKISO_1	21	4,755	19	-3.24627	2.11801
WAKISO_2	22	4,870	17	-3.19496	-4.37463

Plant height

The DDF varied from 72 days to 133 days with stdev of 14.4 while MTD varied from 97 days to 154 days with stdev of 14.0 (Fig 1). Plant height varied from 70 days to 134 days with stdev of 16.1 and tiller number varied from 5 days to 20.2 days with stdev of 3.57 (Fig 2).

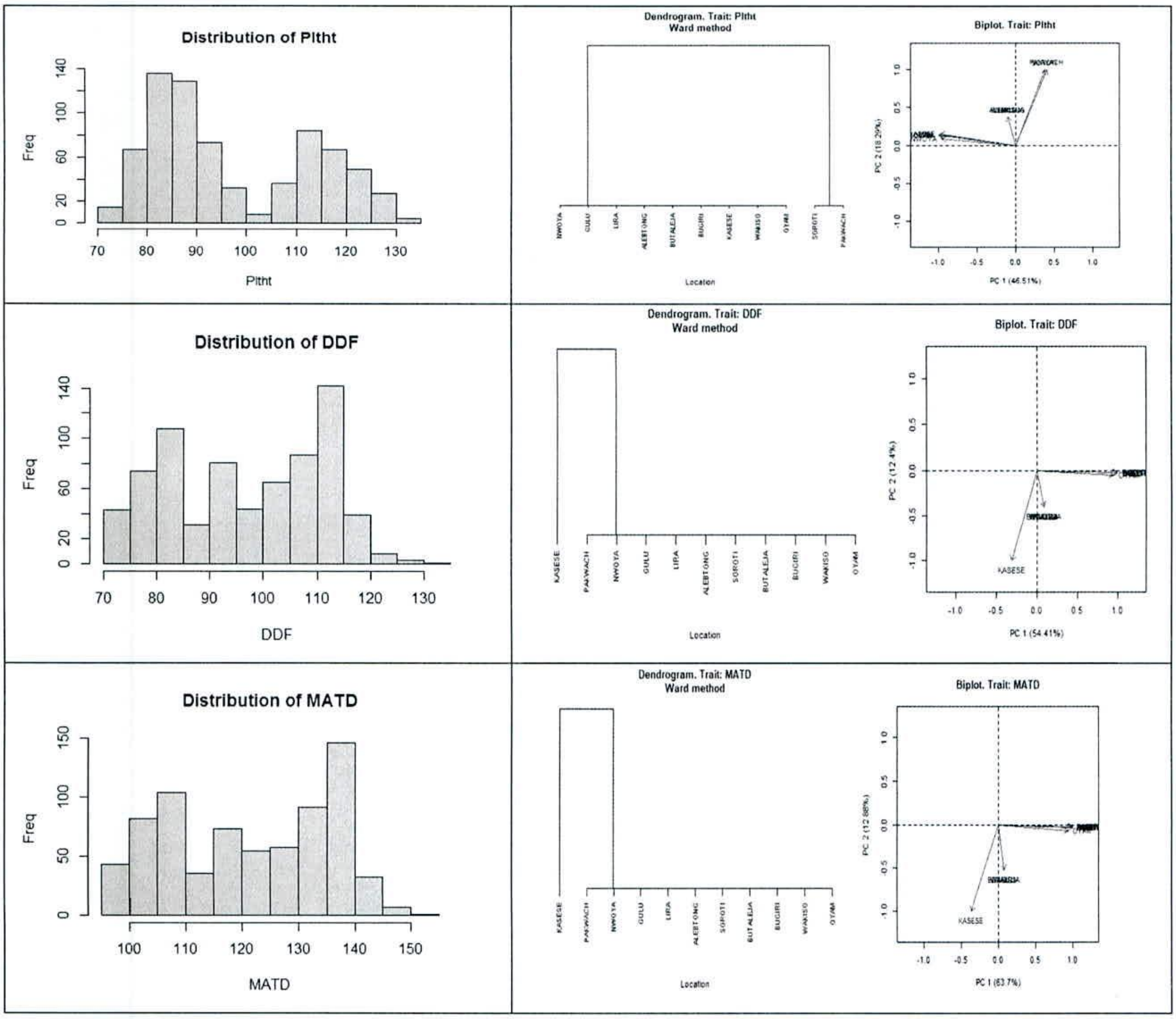

Figure 2: Distribution pattern and dendrogram for plant height, DDF and MATD

Diseases

RYMV is the most important production constraint under lowland rice production system. Total yield losses have been reported in susceptible varieties. Resistance breakdown in previously resistant varieties have been reported (Lamo et al 2021). It is a standard measure/rule of thumb to always introgress resistance in the background of any materials during development process. On a score range of 1-9, there was disease score of 1-5, mean of 1.39 at stdev (1.1) implying that most of the lines showed tolerance and resistance to RYMV. There were significant interactions among genotypes, environments and dendrogram showed three clusters; Lira, Gulu, Nwoya and Pakwach in one cluster, Alebtong, Wakiso and Butaleja in a second cluster and then Oyam and Kasese in the third cluster.

Narrow leaf brown spot is an important yield reducing and quality reducing disease. Limited sources of resistance have been reported (Lamo et al 2021). It important to integrate this trait in any the breeding program. On a score range of 1-9, the was disease score of 1-5 with mean of 2.67 at stdev (1.0) implying that most of the lines showed tolerance and resistance to narrow leaf spot. There were significant interactions among genotypes, environments and dendrogram showed three clusters; Lira, Gulu, Nwoya and Pakwach in one cluster, Alebtong, Wakiso and Butaleja in a second cluster and then Oyam and Kasese in the third cluster.

Bacterial leaf streak is a widespread disease under lowland production system. Limited sources of resistance have been reported (Lamo et al 2021). It important to integrate this trait in any the breeding program. On a score range of 0-9, the was disease score of 0-1 with a mean of 0.08 at stdev (10.27) implying that most of the lines showed resistance to narrow bacterial leaf streak.

Leaf blast is the second most important disease of irrigated rice after RYMV. It is important under upland and lowland conditions. It important to integrate this trait in any the breeding program. On a score range of 1-9, the was disease score of 1-5 with a mean of 1.42 at stdev (1.01) implying that most of the lines showed resistance to narrow bacterial leaf streak.

Bacterial leaf blight is important disease of irrigated rice. It important to integrate this trait in any the breeding program. On a score range of 0-9, the was disease score of 1-5 with a mean of .09 at stdev (0.73) implying that most of the lines showed resistance to bacterial leaf blight.

4.0 RESULTS OF FARMERS PARTICIPATORY VARIETY TRIALS

Rice value chain actors were invited for a field selection exercise of rice varieties at crop maturity. Selection was conducted in one replicate of NPT trial comprising 11 genotypes. Each participant had to select 2 best lines and provide two reasons for his/her preference. In the analysis the best genotype was given a weight of 3 while the second best had a weight of 1 and genotypes not selected a weight of zero (0). The team comprised of farmers, seed traders, grain traders, extension staff, millers, restaurant cooks and consumers. Similarly, the most preferred reason for selecting a variety had a weight of 3 while the second best a weight of 1. The selection took place in four locations: Wakiso, Lira, Gulu and Kasese. Overall, there were 132 participants (51 males and 31 females).

Results revealed that male participants mentioned 15 traits that directed their variety selection (Table 9). The most preferred variety trait was aroma, slender grain shape, uniform flowering, grain weight in descending order. Female participants on the other hand mentioned 16 important traits and the most important reasons being grain weight, slender shape, uniformity in flowering and uniform plant stand in descending order of preference (Table 9).

Table 9: Preferred genotype trait by gender

		Male		Female	
No	Train	Weight score	Rank	Weight score	Rank
1	Grain taste (aromatic)	98	1	14	5
2	Grain shape (slender)	77	2	48	2
3	Flowering uniform	21	3	35	3
4	Grain weight (heavy)	36	4	49	1
6	Grain (easy threshing)	18	5	0	
7	Tiller (high tiller)	17	6	13	
8	Panicle number (high)	11	7	4	
9	Panicle length (long)	10	8	2	
10	Plant stand Uniform	9	9	30	4
11	Disease resistance (grain discoloration)	8	10	6	
12	Maturity (early)	7	11	2	
13	Grain shape (medium)	3	12	5	
14	Disease resistance (neck blast)	3	13	1	
15	Maturity (medium)	2	14	3	
16	Panicle excersion (well)	0	15	2	

Male participants selected 9 of the 11 varieties with the most preferred being MET 12, PR 107, AGRA 55 and ARU 1189 in descending order of preference (Table 10). Female participants selected 7 out of 11 genotypes with PR 107, ARU 189, MET 12 and KOMBOKA in descending order of preference (Table 10).

Table 10: Preferred genotypes by gender

No	Genotype	**Male**		**Female**	
		Weight score	Rank	Weight score	Rank
1	MET 12	84	1	35	3
2	PR 107	68	2	66	1
3	AGRA 55	58	3	10	
4	ARU 1189	44	4	49	2
5	MET 20	40	5	20	4
6	WITA-9	8	6	5	
7	KOMBOKA	7	7	13	5
8	MET 16	6	8	6	
9	TXD 306	2	9	0	
10	AGRA 78	0	10	0	
11	IR 1052	0	11	0	

Male participants mentioned 11 traits for rejecting rice genotypes with the most traits being low panicle number, low tiller number, poor panicle excersion, RYMV susceptibility and low grain number per panicle (Table 11). Female participants on the other hand, had 14 reasons for rejection of rice genotypes with the most important reasons being low tiller number, low number of panicles per hill, grain discoloration, and non-uniform flowering in descending order of importance. (Table 11).

Table 11: Reasons for rejection of genotypes

		Male		Female	
No	Reasons for rejection	Weight score	Rank	Weight score	Rank
1	Panicle no (low)	72	1	30	2
2	Tiller (low tiller)	45	2	42	1
3	Panicle excersion (incomplete)	27	3	6	
4	RYMV susceptibility	27	4	15	6
6	Grain per panicle low	21	5	6	
7	Plant height (un preferred short)	18	6	0	
8	Grain filling (poorly filled)	12	7	0	
9	Plant stand not uniform	9	8	0	
10	Grain shape (short)	6	9	3	
11	Disease resistance (grain discoloration)	6	10	21	3
12	Tiller (too many tiller)	0	11	0	

13	Flowering not uniform	0	12	18	4
14	Disease resistance (blast)	0	13	18	4

Male participants rejected 6 genotypes and these included AGRA 78, MET 16, IR 1052, WITA-9, and TXD 306 in descending order (Table 12). Female participants rejected 5 genotypes and the order is AGRA 78, TXD 306, IR 1052 and WITA-9 (Table 12).

Table 12: Genotypes rejected according to gender

		Male		Female	
No	Genotype	Weight score	Rank	Weight score	Rank
1	AGRA 78	69	1	45	1
2	MET 16	63	2	9	5
3	IR 1052	42	3	30	3
4	WITA-9	39	4	15	4
5	TXD 306	27	5	45	1
6	PR 107	3	6	0	
7	AGRA 55	0		0	
8	ARU 1189	0		0	
9	KOMBOKA	0		9	5
10	MET 12	0		0	
11	MET 20	0		0	

5.0 RESULTS OF SENSORY AND ORGANOLEPTIC TESTING OF CANDIDATE VARIETIES

The sensory and organoleptic evaluation was conducted in Lira, Gulu, Soroti, Kasese and Namulonge in 2018 to represent the different rice production ecologies. Lira, Soroti and Kasese represented the lowland rainfed ecology while Gulu and Namulonge represented the upland rainfed ecology.

A total of 13 new rice lines and 5 already released varieties, acting as checks were used in the evaluation. The 13 lines/varieties, grouped/named based on the parental sources of germplasm were: MET (MET 2, 3, 12, 13, 16 and 20); AGRA (AGRA 55, 65 and 78); IRRI (IRRI 1052); ARU (ARU 1189) and NaCRRI (Entry 20 and 22). The check varieties were Namche 5, WITA 9, NERICA 4, Komboka and Supa local. PR 107 was not included in the evaluation because the quantity of grain produced by then was too little to be used. The 18 rice varieties were randomly staged in 4 sets, where each of sets 1 and 2 contained 5 varieties with at least two checks, while sets 3 and 4 each contained 6 varieties with two checks. Each set was evaluated in uncooked and cooked form in every site. According to the breeding program, some of the varietal lines under consideration were lines bred for improvement in aroma. The lines considered to be aromatic were evaluated as sets 3 and 4 while the non-aroma improved lines were evaluated as sets 1 and 2. The non-aromatic sets were considered first not to bias the participants' tastes of aroma. Although the experimental setup distinguished the improved aromatic and non-aromatic lines during the evaluation, it was not declared to the participants to avoid creating any bias. Sets 1 and 2 were evaluated in the morning (between 9a.m and 12noon) while evaluation of sets 3 and 4 was conducted in the afternoon (between 3and 5pm).

For any given set, each raw/milled rice variety was placed on the table in a dull colored paper, bearing its code. The cooked counter parts of the same set were placed next to the raw according to the code numbering. Participants individually observed, tasted, felt, smelt the varieties, and provided feedback using a semi-structured questionnaire. The cooked rice was achieved through the use of a rice cooker. For each rice line/variety, 500 grams was placed in the cooker and 1,000mls of water added. The cooker was labeled with the variety code and the cooking time recorded. The code representing the milled variety did not necessarily represent the same variety in the cooked form as presented in Table 12.

Table 13: Experimental setting for the sensory evaluation of the rice lines

SET ONE				SET TWO			
Code	Cooked	Code	Uncooked/raw	Code	Cooked	Code	Uncooked/raw
1	Namche 5	1	MET 20	1	Namche 5	1	Entry 20
2	WITA 9	2	NERICA 4	2	WITA 9	2	Namche 5
3	NERICA 4	3	Entry 22	3	MET 2	3	ARU 1189
4	MET 20	4	WITA 9	4	Entry 20	4	WITA 9
5	Entry 22	5	Namche 5	5	ARU 1189	5	MET 2
SET THREE				SET FOUR			
Code	Cooked	Code	Uncooked/raw	Code	Cooked	Code	Uncooked/raw
1	Komboka	1	MET 3	1	Komboka	1	AGRA 78
2	Supa local	2	IRRI 1052	2	Supa local	2	MET 12
3	MET 3	3	Komboka	3	MET 13	3	Supa local
4	AGRA 55	4	AGRA 55	4	AGRA 78	4	MET 13
5	MET 16	5	Supa local	5	MET 12	5	AGRA 65
6	IRRI 1052	6	MET 16	6	AGRA 65	6	Komboka

A semi-structured pre-coded questionnaire, which covered both the milled/raw and cooked rice sections was developed for participants to provide their responses. The evaluation covered a total of 611 participants across the 5 different locations, with 200 in Lira, 128 in Gulu, 64 in Soroti, 55 in Namulonge and 164 in Kasese. The sample size outcome was in accordance with the planned sample design that was intended to be greater than 50 but less than or equal to 200 participants per site i.e. ($50<S\leq200$, where S is sample size). The data generated was entered in to MS Excel 2010 and analyzed using Stata version 11. Weighting score was used to determine preferred qualities for rice as

well as the most important/preferred varieties among the non-aroma and the proposed aromatic varieties.

The socioeconomic characteristics of respondents varied across the five locations. For instance, more than 50% of participants in 4 testing sites (Gulu, Lira, Namulonge and Soroti) were males, while in Kasese, 59% of respondents were females. The average ages of participants in Soroti and Kasese were more than 40 years (41years for each), whereas that of the other 3 sites (Gulu, Lira and Namulonge) were below 40 years old, i.e. 34 years, 35 and 36years for Gulu, Lira and Namulonge, respectively. The majority of respondents falling within 40years and below was a good representation for rice evaluation because the main source of carbohydrates in the diet of this category of the Ugandan population (the young generation) is skewing more towards rice than the traditional sources such as millet, cooking banana (matooke), sweet potato and cassava.

The role of respondents along the value chain varied as shown in Table 13. More than 60% of respondents from Namulonge were consumers while that of Soroti and Kasese were rice grain farmers. The participants from Lira and Gulu were more or less balanced between traders and grain farmers as the majority. There was representation from other value chain nodes even though in small numbers, such as millers, extension, seed farmers, and restaurant operators. It was important to consider the different nodes of the value chain in order to elicit the interests and preferences of the whole value chain for inclusivity in the breeding process.

Table 14: Role of participants along the rice value chain

Role in the rice value chain	Percentage of participants (%)				
	Namulonge	Lira	Soroti	Gulu	Kasese
Seed farmer	7.27	3.50	0.00	0.00	0.00
Grain farmer	10.91	37.50	62.50	29.69	68.29
Miller/processor	3.64	9.50	12.50	20.31	2.44
Trader	1.82	38.50	6.25	26.56	12.20
Extension	0.00	1.50	12.50	0.00	2.44
Restaurant/cooking	12.73	1.00	0.00	0.00	7.32
Consumer	63.64	8.50	6.25	23.44	7.32

Quality attributes considered in milled rice in order of preference

The quality attributes preferred by the participants varied across locations and rice category (milled raw and cooked) as presented in Table 14. Namulonge site, which was dominated by consumers, had aroma as the most important attribute for both milled and cooked rice. Lira's most important preferred attribute in rice was similar to that of Namulonge, even though evaluation in Lira was predominantly executed by traders and farmers. Soroti district preferred the white color in milled rice and aroma in cooked rice as their main attribute of consideration. Gulu and Kasese districts on the other hand varied completely from the rest of the sites. Gulu considered the attributes of cleanliness and color (white) for milled rice and wholeness for cooked rice. Kasese respondents valued the size of grain (big) for milled rice and texture (soft) for cooked rice

Table 15: Quality attributes for milled/raw and cooked rice in order of preference

Quality attributes preferred in milled/raw rice						Quality attributes preferred in cooked rice					
	Total weights of attributes of rice based on ranking					Quality attributes	Total weights of attributes of rice based on ranking				
Quality attributes	Namulonge	Lira	Soroti	Gulu	Kasese		Namulonge	Lira	Soroti	Gulu	Kasese
Aroma	181	686	104	188	436	Aroma	96	56	37	78	222
Cleanliness	62	273	12	296	116	Size (medium)	44	32	11	51	134
Color (white)	113	257	184	296	448	Stickiness	35	26	17	71	255
Size (big)	96	140	124	160	500	Texture (soft)	24	18	7	39	316
wholeness (not broken)	20	151	28	132	100	Taste	0	10	0	28	4
Length (long grain)	47	0	0	. 12	0	Wholeness	0	10	0	268	40
Taste	101	96	68	16	148	Color (white)	0	0	0	5	21

The most preferred varieties by the participants

Participants recorded their most preferred varieties for both milled and cooked rice among both the weak-aromatic and strong-aromatic varieties. Preferences varied across locations as presented in Table 15 and 16. Among the non-aromatic category, the most preferred milled/raw varieties in descending order were Met 20, met 2, entry 20, ARU 1189 and Wita 9. The cooked ones on the other hand were met 2, Nerica 4, Met 20, Namche 4 and Entry 22.

Table 16 The milled and cooked rice varieties in order of preference among the weak aromatic category

Milled rice								Cooked rice						
	Namulonge	Gulu	Lira	Soroti	Kasese	Total			Namulonge	Gulu	Lira	Soroti	Kasese	Total
Met 20	9	69	155	13	89	335		Met 2	5	95	125	13	47	285
Met 2	5	53	44	11	78	192		Nerica 4	16	8	91	0	43	157
Entry 20	12	18	67	32	23	152		Met 20	11	54	55	11	21	151
ARU 1189	20	35	44	0	16	115		Namche 5	15	19	25	22	34	116
Wita 9	6	17	34	12	23	92		Entry 22	9	0	55	0	29	92
Namche 5	12	20	11	12	34	88		Entry 20	16	19	0	26	23	84
Entry 22	16	0	0	26	7	49		Wita 9	3	16	13	11	41	83
Nerica 4	12	0	0	0	0	12		ARU 1189	18	0	0	13	16	46

Table 17 The milled and cooked rice varieties in order of preferences among the strong-aromatic category

Milled/raw rice								Cooked rice						
	Namulonge	Gulu	Lira	Soroti	Kasese	Total			Namulonge	Gulu	Lira	Soroti	Kasese	Total
AGRA 78	11	23	100	21	73	229		Met 3	5	62	67	26	35	194
Met 3	7	51	100	38	14	210		Met 13	0	53	86	11	23	172
Supa local	14	11	20	12	71	127		Komboka	6	5	62	29	47	148
Komboka	7	15	43	12	31	107		AGRA 78	9	79	0	0	23	111
Met 12	18	47	20	11	0	96		Met 16	5	31	44	0	23	103
Met 13	0	39	20	11	9	79		AGRA 65	5	0	57	11	12	84
IRRI 1052	0	15	33	0	0	48		Supa local	25	7	0	0	47	79
AGRA 55	32	0	0	0	14	46		Met 12	7	39	0	11	12	69
AGRA 65	0	16	0	0	9	25		IRRI 1052	5	10	22	0	12	49
Met 16	0	7	0	0	7	14		AGRA 55	14	10	0	13	0	37

Sensory and organoleptic evaluation was executed for PR 107 line against four varieties as the benchmark (Wita 9, Namche 5, Nerica 4 and Supa local) in Amolatar with a total of 60 participants and the preference for the varieties is as presented in Table 18.

Table 18 Milled and cooked rice varieties in order of preferences among farmers in Amolatar

Milled rice							Cooked rice					
Varieties	Set 1	Set 2	Set 3	Set 4	Total		Varieties	Set 1	Set 2	Set 3	Set 4	Total
PR 107	18	11	22	12	63		PR 107	17	12	15	13	57
Nerica 4	19	9	10	8	46		Namche 5	11	6	16	14	47
Supa local	4	14	9	10	37		Supa local	8	16	7	9	40
Namche 5	6	7	6	14	33		Wita 9	5	13	9	10	37
Wita 9	2	11	8	7	28		Nerica 4	11	8	6	10	35

6.0 MILLING QUALITIES OF THE CANDIDATE VARIETIES

Candidate varieties PR 107, MET 12, ARU 1189, AGRA 55, MET 20 and WITA-9 were milled using three different machines, namely single stage (pass) mill, two stage mill and multi stage, modern rice mill. There was highest milling recovery under multi stage, modern rice mill for all the taste lines. There was consistently higher milling recovery for PR 107 and MET 20 than the other varieties evaluated.

Key physicochemical properties are rice are gel consistency (GC), alkali digestion, amylose content (AC).Gel consistency is a method used identify rice that cooks soft and hard. It is determined by measuring the cold paste viscosity of cooked milled rice flour using graduated index to distinguish cooked rice texture. A total of 100 mg of milled rice flour was placed in 2.0 mL of 0.2 N KOH, heated for 8 min in vigorously boiling water and allowed to cool in an ice-water bath, and the gel length was measured. The gel consistency values are classified as soft (61-100 mm), medium (41–60 mm) or hard (26–40 mm), which are positively correlated with gelatinization temperature of high amylose rice, and negatively correlated with protein content. When gel consistency is hard, cooked rice tends to be less sticky. Harder gel consistency is associated with harder cooked rice. When gel consistency is soft, cooked rice has a higher degree of tenderness. A total of 7 lines PR 107, MET 12, ARU 1189, AGRA 55, MET 20 and WITA-9 were assessed for gel consistency. Results that all test lines had gel consistency values more than 61mm implies that they all cook soft. Rice consumers in Uganda prefer soft rice.

Alkali spreading value, related to the gelatinization temperature of raw starch granules. In order to assess the alkali spreading value six grains of milled rice was placed in 100 mL of 1.7% KOH at 30 °C for 23 h according to Little *et al.*, (1958). Scores of spreading was measured where on seven point scale (1 = intact, 7 = greatly dispersed). The scaled are Grain not affected (low alkali digestion value)-score 1; Grain swollen (low alkali digestion value)-score 2; Grain swollen, collar incomplete and narrow (low alkali digestion value) =3, Grain swollen, collar complete and wide (intermediate alkali digestion value) =4, Grain split or segmented, collar complete and wide (intermediate alkali digestion value) =5, Grain dispersed, merging with collar (high alkali digestion value) =6, Grain completely dispersed and intermingled (high alkali digestion value) =7. Results shows that PR 107 is the most soft when cooked, while all other lines are eaually sift on cooking.

Intermediate Amylose is 18%-24% and all the candidate varieties are within the range implying that they do not paste on cooking and are not hard when cooked.

Table 19: Selected milling and post-harvest grain characteristics

No	ITEM	PR 107	MET 12	ARU 1189	AGRA 55	MET 20	WITA-9
1	Milling Recovery Single stage (pass) mill	60	58	65	59	63	60
2	Milling Recovery Two stage (pass) mill	68	65	68	64	65	64
3	Multi stage, modern rice mill	72	68	72	NA	71	66
4	Amylose content	21.6	22.0	23.1	20.1	21.8	23.2
5	Alkali spreading value	6	5	5	5	5	5
6	Gel consistency (mm)	63	65	66	66	65	65

7.0 STATUS OF SEED

Breeder and foundation seed being produced by NaCRRI waiting for release before they are other stakeholders along the value-chain. At the moment details of seed available are summarized in Table 17.

Table 20: Seed production status

No	Line	BREEDER SEED Kgs	Foundations
1	PR 107	25	1 acre planted expect 3 tons
2	AGRA 55	27	1 acre planted expect 3 tons
3	ARU 1189	27	1 acre planted expect 3 tons
4	MET 12	42	1 acre planted expect 3tons
			Harvesting was done in Jan, 2020

8.0 CONCLUSIONS AND RECOMMENDATIONS

Based on results of yield performance, response to diseases and PVS, the best performing rice varieties are MET 12, PR 107, AGRA 55, MET 20 and ARU 1189. Of the 5 lines 4 have been presented for release due to acceptability, including cooking and milling qualities, and stability is yield and reaction to diseases in the field.

9.0 SPECIAL FEATURES OF CANDIDATE VARIETIES

Detailed special attributes of the test candidate varieties are summarized below.

PR 107

1. Early maturing (95 days to maturity)
2. Moderate aroma
3 Has straw colored grains
4 Heavy grains 34grams/1000grains similar to SUPA V88
5 Has distinctive erect flag leaf
6 Tolerant to RYMV, Rice blast, BLB, Narrow Leaf spot and BLS
7 Yield average 5780 Kgs/ha

MET 12

1 Early maturing (102 days to maturity)
2 Aromatic
3 Has straw colored grains with weak purple tip
4 Slender grains line Basmati
5 Medium grains 25grams/1000grains similar to Basmati 370
6 Long culm (76 cm)
8 Tolerant to RYMV, Rice blast, BLB, Narrow Leaf spot and BLS
9 Yield average 5980 Kgs/ha

MET 20

1. Early maturing (115 days to maturity)
2. Moderate aroma
3. Has straw colored grains with strong purple tip
4. Heavy grains 36grams/1000grains slightly bigger than the preferred SUPA V88.
5. Long culm (80 cm)
6. Tolerant to RYMV, Rice blast, BLB, Narrow Leaf spot and BLS
7 Yield average 4760 Kgs/ha

ARU 1189

1. Medium maturing (130 days to maturity)
2. Moderate aroma
3. Has straw colored grains with weak purple tip
4. Heavy grains 31grams/1000grains
5. Basal leaf sheath color: green with purple lines
6. Tolerant to RYMV, Rice blast, BLB, Narrow Leaf spot and BLS
7. Yield average 6520 Kgs/ha

Table 21 Qualitative description of the candidate varieties

	Qualitative Description	PR 107	MET 12	MET 20	ARU 1189	SUPA	KOMBOKA
1	Basal leaf sheath color	Green	Green	Green	Green with purple lines	Green	Green
2	Anthocyanin coloration on the outer surface of the sheath on the penultimate leaf	Absent	Absent	Absent	Weak	Absent	Absent
3	Distribution of anthocyanin on leaves	None	None	None	On margins only	None	None
4	Leaf pubescence	Intermediate	Smooth	Smooth	Intermedia te	Interme diate	Intermediate
5	Anthocyanin color of collar	Light green	Green	Green	Green	Green	Green
6	Ligule color	Yellowish green	Yellowish green	Yellowi sh green	Light Purple	Yellowis h green	Yellowish green
7	Ligule shape	Acute to acuminate	Acute to acuminate	2-Cleft	Acute to acuminate	2-Cleft	Acute to acuminate
8	Anthocyanin color of nodes	Absent	Absent	Absent	Purple	Absent	Absent
9	Color of internodes no ACYN underlying	Light green	Light green	Light green	Green	Light green	Light green
10	Attitude of FL blade	Erect	Semi-erect	Semi-Erect	Semi-erect	Semi-erect	Semi-erect
11	Panicle type culm curve	Upright	Semi-upright	Semi-upright	Semi-upright	Semi-upright	Upright
12	Lemma: shape apiculus	Curved	Pointed	Curved	Curved	Curved	Curved
13	Lemma: Color	Straw	Straw	Straw	Straw	Straw	Straw
14	Lemma: coloration of keel tip	Very weak	Medium	Mediu m	Medium	Medium	Medium
15	Lemma: coloration of keel below	Very weak	Medium	Mediu m	Medium	Medium	Medium
16	Aroma	Moderate Aroma	Aromatic	Modera te Aroma	Moderate Aroma	Strong Aroma	Moderate Aroma

Table 22 Quantitative descriptors of the candidate varieties

	Quantitative Description	PR 107	MET 12	MET 20	ARU 1189	SUPA	KOMBO KA
1	Culm length	52	76	80	55	74	54
2	Duration 50% flowering	60	65	78	90	115	82
3	Maturity period	95	102	115	130	155	120
4	Flag leaf length	43	41	37	37	50	35
5	Flag leaf breath	1.3	1.2	1.7	1.2	1.7	1.6
6	L/Bratio	33.9	34	21.1	31.4	29.4	29.4
7	Panicle length	25.8	23.9	21.2	23.2	24	24
8	1000 grain wait at 14%mc	34	25	36	30	33	26
9	Grain width milled	8.2	8	7	8.1	7.5	8.1
10	Grain length milled	2.8	2.5	2.6	2.5	2.4	2.5
11	Grain L/W ratio	2.93	3.20	2.69	3.24	3.13	3.24

Table 23 Reaction to major biological stresses

	Stresses	PR 107	MET 12	MET 20	ARU 1189	SUPA	KOMBOKA
1	RYMV	Resistant	Resistant	Resistant	Tolerant	Susceptible	Tolerant
2	Blast	Resistant	Resistant	Resistant	Resistant	Susceptible	Resistant
3	Bacterial leaf blight	Resistant	Resistant	Resistant	Resistant	Susceptible	Resistant
4	Bacterial Leaf Streak	Resistant	Resistant	Resistant	Resistant	Susceptible	Resistant
5	Narrow brown leaf pot	Resistant	Resistant	Resistant	Tolerant	Susceptible	Tolerant

10.0 PROPOSED NAMES

Table 24: Proposed names of varieties

No	Code	Registration name	Other local names
1	PR 107	NARORICE-1	NamChe-7
2	MET 12	NARORICE- 2	NamChe-8
3	MET 20	NARORICE- 3	NamChe-9
4	ARU 1189	NARORICE- 4	NamChe-10

11.0 AREAS TO BE GROWN IN

All rainfed lowland areas in the country are suitable for production of these rice varieties.

12.0 SUGGESTED MAINTENANCE PROCEDURE

Seed: Certified seed from credible source need to be procured. Germination test to be conducted a week before planting and appropriate adjustment for seed rate made.

Spacing
The rice variety should be spaced at 20cm between the rows and 20cm within the row 1-3 plant per hill. If the location has well puddled seed bed, then transplanting is recommended. In the case of dry planting, direct seeding is recommended.

Fertilizer
Nitrogen and phosphorus are the most limiting nutrient for rice production in the country. The fertilizer amount to be applied will depend on the fertility of the soil, how long the land has been used without fertilizer application and the amount of yield expected. 80Kg/ha N, 30 Kg/ha P and 30kg/ha K is recommended.

Weed control
It is important that weeds are not allowed to seriously compete with the crop especially in the first 45 days of growth.

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