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Rice Improvement for Irrigated Lowland Agro-ecologies of Ethiopia: Achievements, Opportunities, Challenges and Future Directions

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Abstract Rice is an important food grain crop contributing one third of nutrition and caloric intake in the world. It has a wide range of adaptation that led to evolution of thousands of varieties having diverse cooking, eating and nutritional characters. In Ethiopia, rice is one of strategic commodity that is expected to promote agricultural production. The country has a potential of 3.7 million ha land for irrigated low land rice production. Irrigated rice research recently started in 2001. Since then research on irrigated rice variety development has been conducted by both Somalia Pastoral and Agro-pastoral Research Institute (SoPARI) and Werer agricultural research center (WARC). Irrigated rice improvement program works on strategies such as broadening the genetic bases, stress screening, improvement for additional merits and parental selection for future improvement. So far, more than 2000 rice germplasms have been introduced and evaluated with the objectives of developing high yielding and salinity tolerant varieties. As the result, nine high yielding irrigated rice varieties have been released following the variety development procedures and up 10 salt tolerant genotypes were identified. In addition, 8 genotypes with different grain quality (physical, nutritional and cooking) were identified and three high yielding genotypes are promoted to variety verification trial. However, the genetic improvement is totally dependent on the introduction of rice germplasms. Therefore, it is advisable to establish national crossing block with modern breeding tools and improvement program for development of irrigated rice genotypes for future high yielding, stress tolerant and nutritionally rich rice varieties. Moreover, physical capacity building of the irrigated rice research program is very crucial.

Keywords Improvement, Irrigated rice, Genotype

1. Introduction

Rice is one of the most important food grain crop with regard to human nutrition and caloric intake. It is known by its nutritional diversification with wide range of adaptation that led to evolution of thousands of varieties having diverse cooking, eating and nutritional characters [1]. Because of this wide range of diversification, it is a staple food for more than half of the world population providing one fifth of calorie and 15% protein consumption [2, 3]. In Ethiopia, the second populous nation in sub Saharan Africa, rice is becoming the strategic commodity that has received a due emphasis in promotion of agricultural production. It is considered as one of the alternative agricultural technology for farmers for efficient utilization of marginal resources [4]. Ethiopia has considerably vast agro-ecologies suitable for rice production which is unsuitable for production of other food crops [5]. Generally, the country has a potential of 3.7 million ha land for irrigated low land rice production [5]. Despite this, lack of well adaptable variety along with appropriate packages as well as pre- and post-harvest technologies such as row planters, harvesters, seed cleaners and milling machines are the major challenges for expansion of rice production and utilization in the irrigated lowland areas of Ethiopia.

Rice research in irrigated areas was started in 1969 and continued until 1972 (progress reports, 1970, 1971 and 1972). Then after, it was discontinued for many years and reinitiated in 2001 by introducing 50 rice genotypes from the rice national research program which was coordinated at that time from Pawe Agricultural Research Center. Since then research on irrigated rice technologies development has been conducted by both Somalia Pastoral and Agro-pastoral Research Institute (SoPARI) at

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Wabe-Shebelle basin and Werer agricultural research center (WARC) at Awash basin. The variety development works had two parts. The first part included rice varieties adaptation trial and the second one was introduction and evaluation of rice germplasm. The genetic improvement work was totally dependent on the introduction of rice germplasms mainly form International Rice Research Institute (IRRI) and Africa Rice Center. So far, more than 2000 rice germplasms have been introduced and evaluated in different locations of Afar and Somali regions with the objectives of developing high yielding and salinity tolerant varieties. Therefore, nine high yielding irrigated rice varieties have been released following the variety development procedures [6] but no salinity tolerant varieties were released. However, up to 10 salinity tolerant rice genotypes (up to 12dS/m) were identified. Note that the rice crop is very sensitive to salinity beyond 3dS/m. In addition to variety development works, research on rice production practices such as sowing date, irrigation water application intervals, seed rate, fertilizers application rate and time, sowing method and weed management have been conducted and recommended. Using the released and adapted rice varieties and the rice production practices developed by the research centers, the extension departments of Werer and Gode Research Centers along with the development agents conducted rice technologies demonstration works strongly on agro-pastorals' fields and the results were very impressive. Despite these all research efforts, rice production has not in place in both regions mainly due to lack of rice milling machines.

This manuscript, therefore, is briefly discussed on progresses made so far in rice varieties development for lowland irrigated agro-ecologies, opportunities, challenges as well as future research and development directions.

1.1. Irrigated Rice Production Trend

Nationally the production rice increased from 112,443 Quintals (2005/06) to 1,360,007 Quintals (2016/17) with 7.25% increase in production and 484,181 ha in terms area [7]. The above mentioned progresses were mainly in midland areas of the country. The production in the last two years (2016/17) showed 6.25% increase. Although there is high potential in lowland arid and semiarid areas, it was not yet utilized. The lowland irrigated areas like Afar, Somali, Gambella, Oromia and similar agro-ecologies production data were not documented in CSA but the seed multiplication, research results, existing potential and opportunities shows there should be especial concern to exploit it.

1.2. Research Strategy

Irrigated rice improvement program focused on releasing of high yielding and salt tolerant varieties through the following methods.

1. Broadening the genetic bases of rice through introduction for selection and further breeding works.
2. Considering climate and other abiotic factors as opportunities for genotypes screening.
3. Evaluation of rice genotypes for their additional merits (nutrition and grain quality).
4. Identification of mega environments for irrigated agro ecologies.
5. Identify the source parental lines for different desirable traits in the future crossing program.

1.3. Germplasm Introduction

Since the establishment of rice research more than 2000 germplasm were introduced from International Rice Research Institute (IRRI), Africa Rice and national research institutes form east and South African countries. Most of the genotypes were high yielding genotypes. The remaining were for heat and salinity tolerance. Few of them had merits of grain quality such as nutrition, aroma and taste.

Table 1. Number of Germplasms Introduced, Source and Unique Characters at Werer Agricultural Research Center (2004-2018)

Year	No. of germplasms	Source	Character
2007	72	IRRI	Salt Tolerant
2009	39	Africa Rice	High yielding
2010	162	IRRI	High Yielding
2011	347	IRRI	High Yielding , Heat Tolerant
2012	78	Africa Rice	High yield, Quality
2013	107	IRRI	High yield. Salt tolerant
2016	111	IRRI, Egypt	High Yielding, Salt and Heat tolerant
2017	93	IRRI	High Yielding, Salt tolerant
2018	118	IRRI	High Yielding, Salt tolerant

1.4. Achievements

1.4.1. Research Work

Most of the research work deals with introduction and evaluation of high yielding genotypes at different evaluation stage. The other is evaluation of salinity tolerant genotypes. Currently, three national variety trials (NVTs) for high yielding and two national variety trial for salinity are under evaluation. Also for the same traits different genotypes are under evaluation under preliminary and lower evaluation stages. In addition, some activities had been conducted regarding grain quality. Moreover, grain quality analysis is currently started at NVT or Variety verification stage. In the short term plan conducting grain quality analysis at lower evaluation will be possible with the equipment like near infrared (NIR) technology. Some of the research conducted and the achievements made will be discussed in the following sections.

1.4.1.1 Evaluation of High Yielding Genotypes

The study in on evaluation of 13 rice genotypes for four years (2010-13) at two location (Werer and Gewane) indicated the mean performance of all the genotypes were superior to the check (2815 kg/ha). The highest grain yield (4314.1 kg/ha) was obtained from WAS 194-B-4-1 followed by WAS 137-B-B-5-3 (4296.6 kg/ha) and WAS 62-B-B-17-2-1-1-1 (4061.7 kg/ha). These genotypes were proceeded to the next evaluation stage for variety verification. The local check was early type, tall and possessed high 1000 grain weight as compared to all the genotypes evaluated (Table 2).

Genetic variability study of 64 different rice genotypes showed the presence of adequate variability in the genotypes studied. This variation could be effectively manipulated using appropriate breeding techniques and program to develop improved varieties. High estimate of heritability and genetic advance were observed in most of the traits, indicating the predominance of additive gene action and the possibility of direct selection through these traits (Table 3). In addition, the phenotypic correlation and principal component analysis showed most of the traits evaluated are important for selection of high yielding genotypes and contributing their share for the wider genetic variability of the genotypes [8].

1.4.1.2 Evaluation for Salinity Tolerance

Salinity is the most common abiotic stress encountered by rice plant, which inhibits its growth and productivity [9]. It is known to cause different kinds of stress in rice at different growth stages thus; limit and delay germination, germination energy, number and duration of seedling emergence, vegetative growth, population density, leaf efficiency, flowering and maturity. Like any other crop species or cereals, salinity has two major effects on rice and in addition to nutritional imbalance. These are osmotic effect and tissue damage [10].

Table 2. Mean Performance Thirteen Rice Genotypes Evaluated at Werer and Gewane (2010-2013)

DESIGNATIONS	DHE	DMA	PLH	YLD	TKW
WAS 137-B-B-5-3	99.067	128.200	67.200	4296.6[ab]	20.0667[bcd]
WAS 194-B-4-1	106.400	132.933	64.933	4314.1[a]	18.6667[de]
WAS 122-IDSA-10-WAS-10	100.267	128.733	66.200	3502.1[cd]	19.2000[bcde]
WAS 131-B-B6-B-B-1	98.600	128.667	63.800	3250.8[de]	20.6000[ab]
WAS 62-B-B-17-2-1-1-1	101.000	130.800	61.333	4061.7[abc]	20.2667[bc]
WAS 62-B-B-14-1-4-2	103.667	128.000	69.200	3930.8[abc]	18.6000[e]
WAS 137-B-B-9-5	103.667	129.667	64.600	3998.9[abc]	19.2667[bcde]
WAS 161-B-6-4FRR-1	104.000	128.867	66.800	3492.8[cd]	18.9333[cde]
WAS 173-B-B-1-2	95.600	125.800	61.800	3940.1[abc]	20.2000[bc]
WAS-196-B-5-2	102.667	130.733	68.667	3960.2[abc]	19.4000[bcde]
WAS 169-B-B-5-3	101.267	128.133	69.667	3879.5[abcd]	20.2000[bc]
WAS 161-B-6-B-1	98.667	127.867	67.600	3648.9[bcd]	21.7333[a]
NERICA-4 (CHECK)	81.867	113.467	70.200	2815.6[e]	21.9333[a]
Mean	99.74872	127.8359	66.30769	3776.313	19.92821
CV	5.957070	5.979573	10.86653	23.85960	9.854396
LSD	4.2821	5.5085	5.1924	649.3	1.4152

Where: DHE: days to heading, DMA: days to maturity, PLH: plant height, YLD: grain yield and TKW: thousand kernel weight, i.e; in each column means followed designated by the same latter are not significantly different.

Table 3. Mean, Range and Genetic Parameters for different Traits of 64 rice genotypes

	Mean	Max	Min	GV	PV	EV	GCV	PCV	H2	GA	GAM
DTE	11.45	13.00	9.00	0.925	1.07	0.145	8.39	9.03	86.44	1.84	16.08
DHE	100.19	118.00	72.00	176.525	177.39	0.865	13.26	13.29	99.51	27.30	27.25
DMA	125.69	145.00	101.00	168.24	173.25	5.01	10.31	10.47	97.10	26.33	20.95
PLH	61.53	87.82	47.25	189.285	189.51	0.225	22.35	22.37	99.88	28.32	46.03
ET	4.63	6.23	3.52	0.568	0.57	0.002	16.27	16.31	99.64	1.55	33.47
YLD	2886.16	5690.41	797.64	266351.9	268561.4	2209.55	17.88	17.95	99.17	1058.76	36.68
PL	19.54	22.91	17.38	1.59	2.97	1.38	6.45	8.81	53.53	1.90	9.726

Where: DTE: days to emergence, DHE: days to heading, DMA: days to maturity, PLH: plant height, ET: number of effective tillers, PL: panicle length, YLD: grain yield, Max: maximum, Min: minimum; GV, PV and PV: genotypic, phenotypic and environmental variance; GCV and PCV: Genotypic and Phenotypic coefficient of variation;H2: heritability in broad sense, GA: expected genetic advance at 5% of selection, GAM: Genetic advance as a percentage of mean

According to Tamire (1994) 36% of the land in Ethiopia is affected by salinity. About 40 % of the area in middle awash is out of production due to salinity [11]. Salinity is expanding in irrigated areas since irrigation is potential for production of rice. Genetic improvement for salinity is one of the research priority. As it is discussed above salinity affect rice plant at different growth stages. Some of the activities conducted at different stages (germination, vegetative and final growth stages) discussed as follows.

1.4.1.2.1 Germination Stage

Although, rice is more tolerant at germination than other growth stages increase salinity causes decrease in the rate and percentage of germination. At lower concentration (0 to 2 ds/m) the effect of salinity do not have higher impact on germination percentage but increase in salinity to higher concentration have negative effect [12]. Two different studies indicated the increase salinity caused the decrease in germination percent, germination energy, germination speed, plumule and radicle length (Table 4). The study by Beakal et al (2016) indicated the regression of mean germination percent on salinity levels showed increase salinity by one ds/m reduced germination by 4.34% between 0 and 12ds/m. In these two studies, the effect of salinity showed decreasing effect in all of the parameters although it was not straight in some. It was more devastating with increasing salinity levels. But the effect was more clearly seen in the three germination characteristics (germination speed, plumule and radicle length). The traits clearly showed NONA BOKRA, IR 71907-3R-2-1-1 and 10T115 are the tolerant variety at the three salinity levels although there had been some variation in some traits.

The germination study by Dawit et al. (2010) on 15 rice genotypes for seven days between 0 and 12 ds/m indicated the significant effect of salinity on reduction of germination percent, plumule and radicle length. Similarly the study by Beakal et al. (2016) on 15 rice genotypes for fourteen days between 0 and 12ds/m showed similar results. But some genotypes like IR 68144-2B-2-2-3-2, IR71991-3R-2-6-1, IR 71907-3R-2-1-1 and IR 71829-3R-10-3 showed relativity smaller reduction [13, 14] which showed their tolerance and survival at higher salinity levels (8 and 12 ds/m).

1.4.1.2.2 Early Seedling Stage

Evaluation score taken at vegetative stage (78 days after sowing) identified five susceptible and five tolerant genotypes but their tolerance to salinity was different at different salinity levels based on the symptoms observed (Table 6). At the salinity concentration with no salt stress, most of the genotypes were vigorous with more number of green leaves and more number of biomass. The genotypes with best look were AT 401 and NERICA 4. At 4 ds/m most of the genotypes were tolerant in exception of five genotypes including the susceptible check (IR 29), they looked a little dry with rolled leaves (Table 6). At higher salinity levels more genotypes appeared susceptible in addition to the five susceptible genotypes. At 4 ds/m AT 401, IR 71829-3R-89-1-1, IR 71907-3R-2-1-2 and IR 72048-B-R-16-2-3-3 had better biomass, leaf health and higher leaf number than the very susceptible ones (IR 59418-B-P-2-2, IR 72593-B-18-2-2-2, IR 73055-8-1-1-3-1 and NERICA 4). At 12 ds/m five genotypes did not survive including the susceptible check (IR 29) (Table 4).

Table 4. Germination Percent, Energy, Speed, Plumule and Radicle Length of 41 Rice Genotypes at different Salinity Levels (0 to 12 ds/m)

Genotype	GP	GE	GS	PL	RL
IR 71829-3R-10-3	98-92	97-91	7.52-5.23	5.12-4.52	8.18-6.16
IR 72048-B-R-16-2-3-3	98-95	92-73	5.73-4.15	5.82-4.17	7.71-6.02
IR 71907-3R-2-1-2	98-92	79-55	5.09-3.62	4.69-3.38	7.41-4.82
IR 71907-3R-2-1-1	98-95	95-92	7.05-5.74	5.90-4.48	9.24-6.82
IR 66946-3R-178-1-1**	96-83	89-75	6.40-4.11	6.08-4.61	7.16-4.99
IR 70023-4B-R-R-12-3-1-1	96-91	93-81	6.89-4.80	6.46-4.67	8.31-3.80
IR 77 674-3B-8-2-2-14-1-A	83-77	75-57	5.38-3.71	6.78-4.38	11.35-10.57
IR 71829-3R-82-1-1	98-94	92-75	5.40-4.02	5.78-4.03	5.84-3.77
IR 76397-2B-6-1-1-1-1	94-90	94-87	6.52-5.08	5.44-4.48	6.68-6.28
IR 28	99-93	97-82	6.58-4.68	5.65-3.75	6.56-4.03
IR 10T110 (IR 83415-B-SD)	100-96	99-88	6.20-4.51	5.58-4.44	5.96-4.65
IR 10T115 (IR 85179-4-1-2)	100-95	100-96	7.55-5.93	5.87-4.77	9.88-6.82
NONA BOKRA	100-97	99-97	7.25-5.85	8.18-6.88	10.41-6.83
AT 401	92-87	87-70	5.36-3.88	5.92-3.97	6.68-3.98
TP 30478	95-95	90-75	3.11-2.66	7.22-5.13	7.29-6.83
TP 30510	95-80	95-75	3.08-2.03	6.31-4.32	7.05-3.59
TP 22013	100-80	95-70	3.02-2.10	7.43-7.22	7.10-6.90
TP Serious (25 genotypes)	100-45	100-0	1.53-0.67	15.58-3.36	8.60-2.43
IR 29*	97-27	-	-	18.33-2.11	4.47-2.46
LOCAL CHECK (NERICA 4)	96-92	61-44	4.39-3.47	4.63-2.84	7.45-3.86

* Susceptible Check ** Tolerant Check, GP= germination percent, GE= germination energy, GS= germination speed, PL= plumule length and RL= radicle length

Table 5. Germination Percent, Plumule and Radicle Length of 15 Rice Genotypes at different Salinity levels (0 to 12 ds/m)

Genotype	GP	PL	RL
IR 59418-7B-21-3	84-4	1.41-0.38	5.39-3.04
IR 59418-7B-27-3	82-26	1.31-0.24	5.41-1.29
IR 61247-3B-8-2-1	85-18	1.13-0.41	5.78-3.38
TCCP266-1-3B-10-2-1	82-25	1.04-0.40	5.95-2.83
IR 68652-3B-22-3	86-26	0.76-0.60	6.96-1.91
IR 69588-4R-P-3-3	81-25	1.20-0.17	6.39-1.89
IR 70870-B-P-2-2	85-25	0.90-0.19	7.03-3.70
IR 68144-2B-2-2-3-2	87-42	0.87-0.35	7.16-2.58
IR 68144-2B-2-2-3-3	83-26	1.18-0.13	5.98-2.19
IR 72593-B-13-1-3-1	84-24	0.95-0.14	6.45-5.13
IR 72593-B-13-3-2-1	84-26	1.04-0.14	5.52-1.35
IR 72593-B-13-3-3-1	85-25	1.08-0.55	7.54-0.97
IR72593-B-18-2-2-2	80-31	1.04-0.27	7.18-1.03
IR29*	82-28	1.00-0.12	5.59-0.48
IR 66946-3R-176-1-1**	87-31	1.29-0.67	7.93-2.41

GP= germination percent, PL= plumule length and RL= radicle length
Source: Dawit (2010)

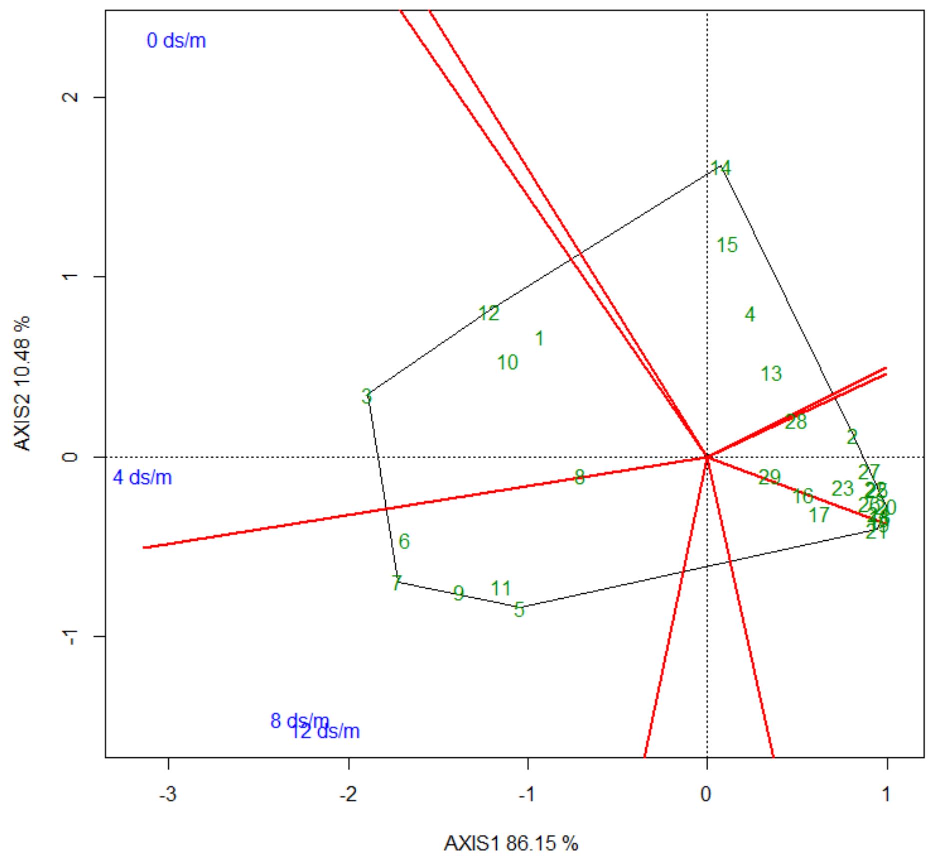
Table 6. Standard Evaluation Scores of Visual Salt Injury at Vegetative Stage

Genotype	0 ds/m	4 ds/m	8 ds/m	12 ds/m	mean	Description
AT 401	1.67	3.00	4.33	5.00	4.11	Moderately Tolerant
IR 29*	1.67	6.33	5.67	6.33	6.11	Moderately Susceptible
IR 55179	3.00	3.00	3.67	5.00	3.89	Tolerant
IR 59418	3.00	4.33	5.67	6.33	5.44	Moderately Tolerant
IR 66946**	1.67	3.67	5.00	5.00	4.55	Moderately Tolerant
IR 70023	1.67	2.33	3.67	5.00	3.66	Tolerant
IR 71810	2.33	3.00	3.67	5.00	3.89	Tolerant
IR 71889	3.00	3.67	3.67	4.33	3.89	Tolerant
IR 71901	2.33	3.67	4.33	3.00	3.66	Tolerant
IR 71902	4.33	4.33	4.33	6.33	4.99	Moderately Tolerant
IR 71991	2.33	2.33	3.67	5.00	3.66	Tolerant
IR 72048	3.00	3.67	4.33	4.33	4.11	Moderately Tolerant
IR 72593	4.33	4.33	4.33	3.67	4.11	Moderately Tolerant
IR 73055	3.67	5.67	6.33	7.00	6.33	Moderately Susceptible
NERICA4	3.00	5.67	6.33	7.00	6.33	Moderately Susceptible

* Susceptible Check ** Tolerant Check

1.4.1.2.3 Final Growth Stage

Pot experiment on salinity screening (0, 4, 8 and 12 ds/m) of 29 rice genotypes based on their grain yield showed GGE biplot divided the four salinity levels in to two sectors. These are lower salinity levels (0 and 4 ds/m) and higher salinity levels (8 and 12ds/m). In the lower salinity levels most of the genotypes performed and even the reduction of grain is very small. But at the higher salinity levels very few genotypes were survived and performed. So these genotypes are considered as tolerant genotypes (Fig. 1). The genotypes are IR 71829-3R-10-3, IR 71907-3R-2-1-1, IR 66946-3R-178-1-1 (tolerant check), IR 71991-3R-2-6-1 and IR 70023-4B-R-R-12-3-1-1 [14,15].



Where 1=AT 401, 2= IR 29, 3= IR 55179-3B-11-3, 4= IR 59418-B-P-2-2, 5= IR 66946-3R-178-1-1, 6= IR 70023-4B-R-R-12-3-1-1, 7= IR 71829-3R-10-3, 8= IR 71829-3R-89-1-1, 9= IR 71907-3R-2-1-1, 10= IR 71907-3R-2-1-2, 11= IR 71991-3R-2-6-1, 12= IR 72048-B-R-16-2-3-3, 13= IR 72593-B-18-2-2-2, 14= IR 73055-8-1-1-3-1, 15= NERICA 4, 16= IR 59418-7B-21-3, 17= IR 59418-7B-27-3, 18= IR 61247-3B-8-2-1, 19= TCCP266-1-3B-10-2-1, 20= IR 68652-3B-22-3, 21= IR 69588-4R-P-3-3, 22= IR 70870-B-P-2-2, 23= IR 68144-2B-2-2-3-2, 24= IR 68144-2B-2-2-3-3, 25= IR 72593-B-13-1-3-1, 26= IR 72593-B-13-3-2-1, 27= IR 72593-B-13-3-3-1, 28= IR72593-B-18-2-2-2, 29= IR 66946-3R-176-1-1

Figure 1. GGE (Genotype main effect plus Genotype by Environment interaction) Biplot Analysis of Grain Yield

1.4.1.3 Evaluation for Grain Quality

1.4.1.3.1 Physical and Nutritional Characteristics

IR 73055-8-1-1-3-1 had the highest value of length-to-breadth followed by IR 29 and NERICA 4. The angle of repose was low in IR 72593-B-18-2-2-2 and IR 72048-B-R-16-2-3-3 whereas, IR 71907-3R-2-1-1, AT 401 and IR 55179-3B-11-3 had the highest angle of repose. According to Mohsenin (1986), the standard value of angle of repose for paddy rice was identified to be 35.83°. The slight increase in angle of repose may be attributed to increase in friction due to increase moisture content during the storage period of paddy rice. Six genotypes had good milling out turn but the released variety NERICA 4 (36°) was slightly susceptible to breakage (Table 7). IR 70023-4B-R-R-12-3-1-1, IR 71991-3R-2-6-1 and IR 72048-B-R-16-2-3-3 had smaller chalkiness value while IR 29, IR 71907-3R-2-1-1 and IR 72593-B-18-2-2-2 had significantly higher chalkiness (Table 7). The rice varieties having minimum amount of chalkiness is considered as good quality grains in comparison with chalky ones [17]. The greater amount of chalkiness in the grain indicates that it is more prone to grain breakage during milling, which results in lower head rice recovery [18]. NERICA 4 (released variety) had high amount of chalkiness followed by IR 29, IR 71907-3R-2-1-1 and IR 72048-B-R-16-2-3-3 which makes it more prone to breakage.

The protein content of 10.56% in IR 70023 was the highest. It was followed by AT 401, IR 71907-3R-2-1-1, IR 73055-8-1-1-3-1 and IR 59418-B-P-2-2 (Table 6). The lowest protein contents were found in IR 29, IR 55179-3B-11-3 and IR 72593-B-18-2-2-2. Generally, the protein content of the 15 rice genotypes ranged from 5.3 to 10.55%. This result agrees with earlier findings by Diako et al. (2011) who found a range of 5.10 to 5.9% on physicochemical characterization of four commercial Ghanaian varieties, and 7.77 to 11.48% on evaluation of indigenous rice cultivar in India [20]. Although the protein content of rice is very low compared to other cereals, it has high quality protein because of its unique composition of essential amino acids such as lysine [21]. IR 29, IR 72593-B-18-2-2-2, NERICA 4 and IR 71829-3R-89-1-1 were found with higher fat content while IR 71991-3R-2-6-1, IR 71907-3R-2-1-2, IR 55179-3B-11-3 and IR 70023-4B-R-R-12-3-1-1 had significantly lower amount of fat (Table 7). The study of Oko and Ugwu (2011) on local rice varieties at Abakaliki region, Nigeria indicated that the fat content of rice varieties ranged from 0.5 to 3.5%. The present study showed higher range of fat content (1.81 to 4.33%). The fiber content of the 15 rice genotypes ranged from 2.90 to 6.15%. The genotypes with higher crude fiber content were IR 71907-3R-2-1-1 and AT 401. Genotype IR 72593-B-18-2-2-2, IR 71991-3R-2-6-1 and IR 29 had smaller fiber content (Table 7). The fiber content ranges from 2.90 to 6.15% which is much more than the finding of Oko et al. (2012) who found 1.00 to 2.50% in the study of 20 local and newly introduced varieties in Ebonyi state, Nigeria but Fadaei and Salehifar (2012) found that the fiber content in the husk of rice is 3 to 5 times higher.

1.4.1.3.2 Physicochemical and Cooking Characteristics

The gel consistency of IR 29, IR 55179-3B-11-3 and IR 72593-B-18-2-2-2 were the highest whereas the gel length was higher in IR 70023-4B-R-R-12-3-1-1, AT 401, IR 71907-3R-2-1-1, IR 71829-3R-89-1-1 and IR 73055-8-1-1-3-1 (Table 8). The gel length was relatively medium in IR 66946-3R-178-1-1, IR 72048-B-R-16-2-3-3 and IR 71991-3R-2-6-1. In this experiment with the exception of few genotypes (AT 401, IR 59418-B-P-2-2 and IR 70023-4B-R-R-12-3-1-1) most of the genotypes had medium gel constancy which tends to remain softer after cooling.

The amylose content was higher in IR 29 followed by IR 55179-3B-11-3 which can be classified under high amylose group and lower in IR 71991-3R-2-6-1, AT 401, IR 73055-8-1-1-3-1 and IR 71901 (Table 8). The genotypes with intermediate amylose content were IR 72593 and NERICA 4. IR 70023, AT 401, IR 71907-3R-2-1-1 and IR 73055-8-1-1-3-1 were found with higher ash content while IR 29, IR 55179-3B-11-3, IR 71907-3R-2-1-2 and NERICA 4 had smaller amount of ash (Table 8). The gruel loss was minimal for IR 59418-B-P-2-2, IR 70023-4B-R-R-12-3-1-1 and IR 72593-B-18-2-2-2.

The range of optimum cooking time of the 15 genotypes ranged from 12 to 34 minutes (Table 8). This is a very wide range where some take very short time others takes very long cooking time. The genotypes with shorter cooking time were IR 29, IR 72593-B-18-2-2-2 and IR 55179-3B-11-3 whereas IR 70023-4B-R-R-12-3-1-1, AT 401 and IR 71907-3R-2-1-1 took longer time to be cooked. Most of the genotypes were not different in elongation ratio but it was relatively higher in IR 71829-3R-89-1-1 and IR 71829-3R-10-3; and lower in IR 70023-4B-R-R-12-3-1-1 and IR 55179-3B-11-3 (Table 8).

1.4.2. Variety Released

As it was discussed above the variety release totally dependent on introduction. Through introduction and evaluation about 9 varieties had been released by Somali Region Pastoral and Agro pastoral Research Institute (SoRPARI) since 2007 (Table 9). Also in 2015/16 three varieties were presented for verification by Werer Agricultural Research Center (WARC). The varieties were namely WAS 137-B-B-5-3, WAS 194-B-4-1 and WAS 62-B-B-17-2.

Table 7. Physical and Nutritional Characteristics of 15 Rice Genotypes

Genotype	LBR	TKW (g)	BD (kg/hl)	AR (°)	CH (%)	Protein %	Fat %	Fiber %
AT 401	2.98	24.00	59.23	42.33	14.54	10.17	2.35	6.07
IR 29	3.14	21.00	57.69	38.33	58.17	5.42	4.33	3.04
IR 55179	2.65d	24.67	62.41	39.67	18.17	6.06	2.17	5.43
IR 59418	2.50	18.17	61.63	36.67	12.26	9.27	2.34	5.97
IR 66946	2.98	25.00	56.63	34.67	12.46	8.24	2.33	4.74
IR 70023	2.84	25.02	60.40	34.00	5.63	10.56	2.17	5.80
IR 71810	2.71	22.00	61.36	37.00	16.36	8.48	2.49	3.88
IR 71889	2.72	18.00	59.09	36.67	12.64	9.17	2.66	5.82
IR 71901	2.45	22.00	60.13	42.67	28.63	9.90	2.58	6.15
IR 71902	2.58	23.00	59.79	36.00	15.91	7.28	2.16	3.66
IR 71991	2.68	23.00	59.27	33.33	11.27	7.75	1.95	2.95
IR 72048	2.74	19.00	56.45	31.67	11.91	7.95	1.81	3.71
IR 72593	2.63	19.00	60.86	27.67	27.55	6.35	2.74	2.90
IR 73055	3.44	24.00	59.19	35.33	12.18	9.52	2.54	5.71
NERICA4	3.06	25.00	59.29	36.00	27.26	7.18	2.69	3.61
Mean	2.81	21.79	59.56	36.13	19.00	8.22	2.49	4.63

Where; LBR= length-to-breadth ratio, TKW = thousand kernel weight, BD= bulk density, AR= angle of repose and CH= chalkiness

Table 8. Physicochemical and Cooking Characteristics of 15 Rice Genotypes

	GL Mm	WUR %	GC	ASV	Gelatinization	Ash (%)	AC	OCT Min	SGL %	ER
AT 401	38.33	1.85	Hard	2.33	High	0.69	High	30.33	5.05	1.15
IR 29	54.00	1.65	Medium	7.00	Low	0.65	High	12.00	5.31	1.13
IR 55179	52.00	1.50	Medium	6.67	Low	0.76	Intermediate	18.33	4.01	1.04
IR 59418	39.67	2.25	Hard	4.67	Intermediate	0.79	Intermediate	25.67	1.94	1.13
IR 66946	42.33	2.15	Medium	3.00	High	0.82	Low	28.33	4.19	1.18
IR 70023	37.33	2.09	Hard	1.00	High	0.90	Low	34.67	2.01	1.03
IR 71810	40.67	1.85	Medium	4.00	Intermediate	0.88	Low	27.33	4.04	1.20
IR 71889	39.00	2.25	Hard	3.00	High	0.90	Low	28.67	3.28	1.21
IR 71901	39.00	1.89	Hard	2.00	High	0.91	Low	30.33	3.44	1.10
IR 71902	46.67	1.99	Medium	4.67	Intermediate	0.72	Low	25.67	3.74	1.13
IR 71991	45.33	1.89	Medium	4.00	Intermediate	0.85	Low	28.33	3.40	1.15
IR 72048	43.67	1.75	Medium	5.33	Intermediate	0.93	Low	20.33	4.04	1.10
IR 72593	51.67	1.69	Medium	6.00	Low	0.97	Very Low	15.33	2.34	1.17
IR 73055	39.33	1.85	Hard	1.67	High	0.94	Very Low	29.00	4.10	1.18
NERICA4	48.67	1.65	Medium	4.67	Intermediate	0.93	Very Low	24.33	4.08	1.17
Mean	43.83	1.89		4.00		0.84		25.24	3.66	1.14

Where; GL= gel length, WUR= water uptake ratio, GC = gel constancy, ASV= alkali spread value and AC= amylose content

Table 9. Variety Released for Irrigated Lowland Agro-ecologies of Ethiopia

No	Variety	Year of Release	Breeder/Maintainer	Altitude (m)	Average Yld (Q/ha)
1	GODE-1 (BG-90-2)	2007	SoRPARI	500	57.07
2	HODEN (MTU-1001)	2007	SoRPARI	500	46.9
3	NERICA-1	2007	SoRPARI	500	47
4	NERICA-2	2007	SoRPARI	500	50
5	SHEBELLE (IR 688059-76-3-3-3-2)	2007	SoRPARI	500	59.15
6	KALLAFO-1/FOFIFFA-3737/	2010	SoRPARI	500	65.5
7	NERICA-14	2010	SoRPARI		-
8	NERICA-15	2011	SoRPARI		62.69
9	NERICA-6	2011	SoRPARI		63.7

Source: Fantahun et al., 2017

1.5. Resources

Currently, irrigated rice research is totally handled by Werer Agricultural research center. At Werer rice improvement program two MSc and Two BSc (one MSc Student) are working. In addition, at Somali and Afar research centers two researchers (MSc) are available for rice research. In terms of location, Werer is the only location currently exploited. But Gewane, Methara, Deho, Gode and Dubti are also the potential areas as a testing locations. But capacitating such areas with irrigation infrastructure is needed. Irrigated rice mostly dependent on field experiments although some facilities are shared with other research programs like lath house and laboratories. In order to grow irrigated rice research more facilities such laboratories (food and nutrition), green house, lath house and cold store should be available.

2. Challenges

Lack of milling machine for research and production is one of the major problem that limits the production and expansion of rice in irrigated areas. Lack wide adaptable varieties and the expansion of salinity are also challenging the production. Genetic improvement without wide range of germplasm is difficult. So establishing the cold room for preservation of germplasm should be the first priority. Also in the genetic improvement and selection including of varieties with good grain quality at lower evaluation is not possible without equipments like Near Infrared (NIR) Technology. So such kind of equipment are important to consider quality parameters. In addition, shortage of expertise in rice especially in regional centers made the improvement and variety development very slow and inconsistent. Moreover, lack experience in rice breeding (crossing) especially from the national program and shortage of budget made the improvement program totally dependent on introduction. Lack of testing location is the other most important factor that hamper the variety release for irrigated lowland agro-ecologies.

3. Future Direction

Due you to its is wide range of nutritional use rice is introduced and production expanding in Ethiopia. For increasing its productivity and wide adaptability, irrigated agroecology is important. For securing sustainable variety development, genetic improvement through conventional and molecular tools is necessary. So establishments of permanent crossing block in needed. Further parental selection for hybrid and inbred development will be done. Also development of inbred parents for different abiotic stress and good grain quality will be conducted. Moreover, integration of modern plant breeding tools in different aspects will make the genetic improvement of rice simple and faster. In addition, mechanization is playing a key role for rice production and expansion. Therefore, due attention must be given for changing traditional rice production system in to mechanized system.

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