Registering a New Green Super Rice Variety Named "*Selam*" for Cultivation in Ethiopia

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Abstract

Background: Rice (*Oryza sativa* L.*)* one of the crops whose importance as a food crop has been rising in Ethiopia. However, lack of high yielding and cold tolerant varieties of the crop has been posing a serious challenge to the production of the crop in the high lands of Ethiopia. This problem undermines the efforts being made to expand the production of the crop in the country.

Objective: Research was conducted to evaluate performances and stability of several cold tolerant lowland green super rice varieties and make recommendations as to which variety is the best to cultivate for high yield and cold tolerance in regions located in northwestern Ethiopia.

Material and Methods: The variety *Yungeng* 31 was named "Selam" after it was officially introduced from China together with 15 other genotypes of the crop in 2014 from China, Chinese Agricultural Academic Science in 2014 and released in Ethiopia in 2020. "Selam" means peace in Amharic. Quarantine tests and preliminary variety evaluation were conducted in 2014 and 2015 main cropping seasons in Andasa and Fogera districts respectively in the Amhara National Regional State in northwestern Ethiopia. The national variety trial was conducted from 2016 to 2018 main cropping season in Fogega, Shire-Maitsebri Jimma and Dembiaya districts. The variety verification trial was conducted in 2019/2020 main cropping season in the same places. *Edige*t and *Fogera-2* were used as standard check varieties. *Shaga* variety which was included during variety verification trial. *Fogera-2* and *Shaga* were released by Fogera National Rice Research and Training Center in 2016 and 2017, respectively. *Edige*t was released by Adet Agricultural research center in 2011. All these varieties were introduced from Africa Rice Center.

Results: The mean grain yield of *Selam* amounted to 4977.6 kg ha^{-1} across the locations over the years, with yield advantages of 32.9% and 17.1% over the *Edige*t and *Fogera-2* varieties, respectively. In the verification trial, *Selam* produced a mean grain yield of 5200 kg ha^{-1} across three on-stations and 4700 kg ha^{-1} across four on-farm sites, enhancing its yield advantage by 17.6% over the Shaga variety. Furthermore, the new *Selam* variety was found to be cold-tolerant and has a white seed color.

Conclusions: According to the findings of this study, *Selam* was found to be a significantly higher grain yielder than standard varieties and stable across the locations and cropping seasons. Moreover, the new variety *Selam* has preferable characteristics like white seed color, long panicle, and uniform maturity. Therefore, the new variety *Selam* was recommended and officially released in 2020 for cultivation by smallholder farmers as well as large scale rice producing farmers in areas with altitudes ranging between 1350 to 1810 meters above sea level and other similar agro-ecologies in Ethiopia.

Keywords: Cold tolerance; High yield; National variety trial; Standard check; White seed color

1. Introduction

Rice has become a major contemporary food crop in Ethiopia. The land coverage under the crop more than doubled, from 30,649 ha in 2012 to 85,289 ha in 2021. The volume of production of the crop also increased from 88,619 tons in 2012 to 268,224 tons in 2021 with an average on-farm productivity level of 3.0 t ha^{-1} in the country (CSA, 2012; CSA, 2021). Although crops such as teff, maize, wheat and barley have dominated cereal production in Ethiopia, rice production has begun to gain significance in recent years. The demand for a shift towards rice in the markets, however, has so far outpaced the local production entailing a modest self-sufficiency rate of only about 20 % (milled rice) and prompting domestic markets to import rice from other rice growing countries (MoANR, 2017).

Ethiopia's geography is noticeable by enormous depressions and hills but the country possesses vast arable lands which are located at high altitudes of more than 2000 meters above sea level. Rice can be grown in a wide agro-

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climatic zone; however, low temperature stress is a major constraint to grow the crop in the highlands of the country. As a result, lack of cold tolerant rice varieties in the high lands is the main factor constraining rice production in the country (Nigussie Zena and Tarekegne Berhe, 2009; Abebaw Dessie *et al.*, 2020) and farmers have faced a serious challenge in their efforts to boost productivity.

Due to its origin in tropics and subtropical regions, rice is more sensitive to cold stress than other cereal crops (Africa Rice, 2018). The rice crop can be damaged by low temperatures (chilling) at different developmental growth stages in rice. Chilling injury at the seedling stage can lead to leaf discoloration or yellowing, leaf rolling or wilting, slowed growth, delayed crop maturation, poor establishment, and spikelet sterility at reproductive stage subsequently, decrease in yield (Junliang *et al.*, 2017; Moraes *et al.*, 2016; Cruz *et al.*, 2013). Optimum mean daily temperature for rice growing ranges from 25 to 35 °C for Indica and 20 to 33 °C for Japonica rice varieties (Yoshida, 1981), and threshold low temperature at reproductive sage of the crop ranges from 18 to 20 °C (Rashid and Yasmeen, 2017). Development and use of cold tolerant varieties have been considered as the most economical and effective way to avoid low temperature damage caused to rice. However, rice breeding for cold tolerance is difficult due to its polygenic nature and inadequate knowledge on the genetic basis of cold tolerance (Junliang *et al.*, 2017).

Green Super Rice (GSR) is a rice variety that can produce high and stable yields under low inputs (nutrients, water, and pesticide) and adverse conditions (Zhang, 2007). Such varieties may play a significant role to boost rice production in Ethiopia. The objective of this study was to evaluate performances of cold tolerant lowland Green Super Rice varieties and recommend a high yielding and cold-tolerant one for cultivation in the northwestern and other parts with similar agro-ecologies in Ethiopia.

2. Variety Evaluation

Observation and preliminary variety trials consisting of 18 rice genotypes including two check varieties were conducted in 2014 and 2015 in Andassa and Fogera, respectively. The trial was advanced to National Variety Trial and evaluated across four locations for three years to further evaluate the performances of the genotypes. A total of 15 genotypes including two check varieties (*Ediget* and *Fogera-2*) were grown at four locations (Fogera, Dembia, Shire-maitsebri and Jimma districts) from 2016 to 2018 cropping seasons. The trials were laid out as a randomized complete block design with three replications with a plot size of 7.5 m^2 (5 m row length with 6 rows of 0.25 m between rows spacing). Direct seeding at the seeding rate of 60 kg ha^{-1} was applied in a row. Two better performing genotypes, *Yungeng 31* and *KB-2*, were advanced to a Verification Trial. The verification trial was conducted at three on-station and four on-farm locations. All other management practices were applied following research recommendations specific to each location. Analysis was performed in SAS 9.3 (SAS Institute, 2009). Duncan's Multiple Range Tested was used for mean separation. *Yungeng 31*, which was released with the name "Selam" consistently out-yielded standard check varieties and other genotypes over the three years and locations (Table 1). *Selam* variety significantly outyielded *Ediget* and *Fogera-2* with a yield advantage of 32.9 % and 17.1%, respectively during National Variety Trial. Similarly, it outyielded 17.6 % and 59.4 % over *Shaga* and *Ediget,* respectively during Variety Verification Trial (Table 2).

Table 1. Mean grain yield and other yield related parameters of 15 lowland green super rice genotypes for cold tolerant at Fogera and Shire-Maitsebri over three years (2016–2018).

Genotype	Code	DTH	DTM	PL	PH	FGP	GY
Yungeng 44	G1	95.3^{c}	132.7^{bcde}	17.6^{def}	81.4^{cde}	114.2^{b}	4347.7^{bcd}
Yungeng 31	G2	91.3^{def}	127.4^{bcde}	19.2^{ab}	87.4^{a}	123.4^{a}	4977.6^{a}
Yungeng 45	G3	94.3^{cd}	134.3^{bcde}	18.5^{bcd}	78.7^{ef}	116.4^{ab}	3830.6^{cde}
Yungeng 38	G4	92.8^{cde}	128.2^{bcde}	19.7^{a}	84.3^{abc}	120.1^{ab}	4366.0^{bc}
Fengdao 23	G5	92.4^{cde}	151.1^{a}	16.7^{ef}	74.5^{hig}	91.7^{ef}	3784.9^{cdefg}
KB-2	G6	92.0^{cde}	128.2^{bcde}	17.1^{ef}	77.1^{fg}	100.9^{cd}	4751.3^{ab}
Songgeng9	G7	84.7^{i}	123.8^{cde}	17.7^{cde}	75.7^{fgh}	95.6^{cdef}	3272.8^{fg}
P-28	G8	89.4^{efgh}	127.9^{bcde}	16.7^{f}	74.6^{hig}	99.1^{cde}	3898.7^{cde}
P-37	G9	87.4^{hig}	122.7^{de}	16.7^{f}	73.6^{hi}	101.7^{cd}	3751.3^{defg}
P-38	G10	100.4^{b}	137.4^{bc}	19.0^{ab}	80.9^{de}	101.7^{cd}	3734.3^{defg}
P-39	G11	88.1^{fghi}	121.3d^{e}	17.2^{ef}	77.4^{fg}	96.3cd^{ef}	3309.2^{efg}
Li Jing 9	G12	86.1^{hi}	122.8^{de}	19.7^{a}	86.6^{ab}	119.0^{ab}	4079.5^{cd}
Li jing 11	G13	103.6^{ab}	138.8^{b}	16.9^{ef}	63.0^{j}	89.3^{f}	3215.5^{g}
Ediget (Check)	G14	90.0^{egf}	120.0^{de}	18.6^{bc}	83.9^{bcd}	93.6^{def}	3746.4^{defg}
Fogera-2/Komboka (Check)	G15	104.6^{a}	136.4^{bcd}	19.7^{a}	72.3^{i}	102.7^{c}	4249.0^{bcd}
Mean		92.8	130.3	18.1	78.1	104.4	3954.3
LSD (5%)		3.4	12.0	0.9	3.0	7.4	523.3

Note: *DH = days to 50% heading; DM = days to 85% maturity; FGP = filled grains/panicle; PH = plant height (cm); PL = panicle length (cm); and GY = grain yield (kg/ha). LSD = list significance difference.*

Table 2. Mean data combined across three on-station and four on-farm sites in variety verification trial in 2019.

Genotype	Days to heading	Days to maturity	Panicle length (cm)	Plant height (cm)	Number of filled grains/panicle	1000Seeds weight (g)	Grain yield kg ha^{-1}
Yungeng31 (Selam)	96	137	21.2	94.5	135.3	28.8	5498.7
Shaga (Check)	92	130	20.0	105.8	108.6	29.4	4677.0
KB-2	92	139	19.3	86.6	114.3	29.3	4282.5
Ediget (Check)	89	130	18.9	86.2	83.7	32.3	3448.7
Adv. (%) over *Shaga*	4.3	5.4	6.0	-10.7	24.6	-2.0	17.6
Adv. (%) over *Ediget*	7.9	5.4	12.2	9.6	61.4	-10.8	59.4

Note: *Adv. (%) = percentage advantages of Yungeng31 (Selam) variety over Shaga and Ediget check varieties.*

In addition to high yield, the variety was found to have a trait of cold tolerance which the other released varieties lack. The combined analysis of variance (Table 3) revealed significant ($P \leq 0.001$) differences in days to maturity, days to heading, panicle length, number of grains produced per panicle and plant height and ($P \leq 0.01$) in grain yield. The variety was found to be tolerant to cold, resistant to major disease (Sheath rot and blast) and have a white seed color. The best candidate varieties (*Yungeng 31* and *KB-2*) were evaluated by the National Variety Release Committee and *Selam (Yungeng 31)* was preferred by farmers, breeders and other stakeholders because of the aforementioned merits across locations and finally officially released for cultivation in June 2020.

Table 3. Mean squares from combined analysis of variance for six agronomic traits of 15 rice genotypes at two locations and three cropping seasons.

Trait	Rep within Envt (2)	Genotype (G) (14)	Environment (E) (5)	Year (Y) (2)	G*E (70)	Error (178)	CV (%)
DTH	1.9^{ns}	651.0***	7247.3***	3429.7***	67.0***	27.3	5.6
DTM	294.4^{ns}	1236.0***	7962.5***	2595.5***	364.3^{ns}	333.0	14.0
PL	3.3^{ns}	25.0***	162.1***	177.0***	3.8***	1.7	7.2
PH	11.1^{ns}	728.9***	3211.8***	4328.9***	62.3***	21.0	5.9
FGP	124.3^{ns}	2272.9***	25684.0***	24872.5***	320.2***	683.8	10.8
GY (t ha^{-1})	166094^{ns}	4776960**	127412672**	217702496**	2552642**	632955	20.1

Note: *DH = days to 50% heading; DM = days to 85% maturity; FGP = filled grains/panicle; PH = plant height (cm); PL = panicle length (cm); and GY = grain yield (kg/ha). ns, ** and *** = non-significant and significant at P < 0.01 and P < 0.001, respectively. Numbers in parenthesis represent degree of freedom for the respective source of variation. CV = coefficient of variation.*

3. Yield Performance

Selam variety produced a mean grain yield of 4977.6 kg ha^{-1} in the National Variety Trial (NVT) program across six environments and significantly ($P < 0.01$) out yielded *Ediget* and *Fogera-2* with yield advantage of 32.9% and 17.1%, respectively. This variety consistently performed better than the check varieties over three years. Upon verification across three locations (Fogera, Jimma and Shire-Maitsebri), *Selam* produced a mean grain yield of 5498.7 kg ha^{-1} from the three on-stations and four on-farm sites with yield advantages of 17.6% and 59.4% over *Shaga* and *Ediget*, respectively.

4. Grain Yield Stability

Grain yield stability of the 15 genotypes was analyzed for three years at two locations (Fogera and Shire-Maitsebri) using GGE biplot. A Genotype which is found at the center of the concentric circle with an arrow pointing to it is considered as an ideal genotype with its high mean yield and stable characteristics. Accordingly, *Selam* (G2) was an ideal genotype with highest mean yield and stability (Figure 1), followed by KB-2 (G6). On the other hand, check varieties *Ediget* (G14) and *Fogera-2/Komboka* (G15) were not close to the ideal genotype in that they were lower yielders and had less stability than *Selam* variety. These results were approved by a mean separation test.

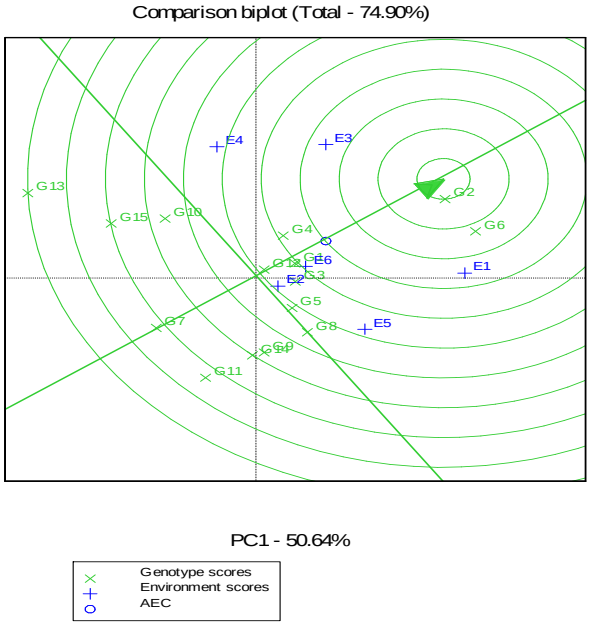

Figure 1. GGE-biplot on genotype ranking for comparison the genotype with the ideal genotype. G1=Yungeng 44, G2 =Yungeng 31, G3 =Yungeng 45, G4 = Yungeng 38, G5 = Fengdao 23, G6 = KB-2, G7 = Songgeng9, G8 = P-28, G9 = P-37, G10 = P-38, G11 = P-39, G12 = Li jing 9, G13 = Li jing 11, G14 = *Ediget* (Check variety), G15 = *Fogera-2/Komboka* (Check variety), E1 = Fogera year-1, E2 = Shire-Maitsebri year-1, E3 = Fogera year-2, E4 = Shire-Maitsebri year-2, E5 = Fogera year-3, E6 = Shire-Maitsebri year-3.

5. Agronomic and Morphological Characteristics

The morpho-agronomic description of newly released variety, *Selam* is presented in Table 4. *Selam* is a white seeded variety with medium seed size (1000 grain weight of 25 gram). It has an erect flag leaf and good phenotypic acceptability which can fit the good character of a high yielding variety. Based on the results of national variety trials and verification variety trials, *Selam* was found to have higher number of grains per panicle than the check varieties (Tables 1 and 2). It was also found to have a longer panicle length (21.2 cm) than the check varieties (*Shaga and Ediget*), 20 cm and 18.9 cm, respectively (Table 2). Moreover, *Selam* has the ability to tolerate cold (Photo 1.) and is suitable for cultivation in the highlands of Ethiopia. It has also a strong culm, implying it has better tolerance to lodging.

Photo1. Response of *Selam* variety to cold at reproductive stage (right *Selam* variety and left other genotypes), implying that *Selam* variety was good for seed fertility whereas other genotypes were week

Table 4. Morpho-agronomic characteristics of *Selam* variety.

Character	Value/description
Variety name	*Selam* (*Yungeng31*)
Adaptation	Fogera, Jimma, Dembiya, Shire-Maitsebri
Altitude (m a.s.l.)	1350–1810
Rain fall (mm)	1296–1561
Seed rate (kg ha^{-1})	60
Fertilize rate (kg ha^{-1})	
Phosphors as P_2O_5	23
Nitrogen as N	69
Planting date	Early June to Late June: depending on the onset of rainfall
Spacing (cm)	25 cm between rows for row drill planting
Days to heading	93
Days to maturity	132
Panicle length (cm)	20
Plant height (cm)	91
Number of grains/panicle	129
Cold tolerance	Very good
Lodging tolerance	Good
Pest resistance	Good
Thereshability	Fair
Shattering	Fair
Seed size	Medium
Growth habit	Erect
1000 grain weight (gram)	25
Caryopsis color	White
Grain yield (t ha^{-1})	
Research field	5.2
Farmers field	4.8
Year of release	2020
Breeder/ maintainer	Fogera National Rice Research and Training Center/EIAR

6. Conclusion

Selam is a variety that significantly outperformed *Ediget* and *Fogera-2* varieties in yield and stability across the locations and years. The variety also possesses a high number of grains per panicle, long panicle length, and white seed color. Farmers also preferred *Selam* variety to the other rice varieties evaluated for its superior performance in terms of grain yield, uniform maturity, and high number of grains per panicle and cold tolerance. Hence, the variety was officially recommended for a large-scale production in major rice growing areas in Ethiopia.

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