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Why Has a Single Rice Cultivar Dominated the Lowland Rice Production Portfolio of Ethiopia for so Long?

Mulugeta Atnaf[1], Abebaw Dessie[1], Fisseha Worede[1], Zelalem Zewdu[1], Assaye Berie[1], and Taddesse Lakew
[1]*EIAR, Fogera National Rice Research and Training Center, Woreta, Ethiopia*

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ሩዝ በኢትዮጵያ የእርሻ ስርዓት ውስጥ ተመራጭ እየሆነ የመጣ ሰብል ነው። የፎገራ አካባቢ የአገሪቱን 68 ፐርሰንት የሩዝ መሬት ሸፋንና 71 ፐርሰንት ምርት ይሸፍናል። የዚህ ጥናት አላማዎች ለምን አንድ ኤክሱ-ጅግና የተባለ የሩዝ ዝርያ በፎገራ አካባቢ ሳይተካ ለረጅም ጊዜ (ከ30 ዓመታት በላይ) በምርት ሂደት ሊቆይ እንደ ቻለ እና ከዚህ ሁኔታ የሚገኙት አስተመህሮቶች ለብሔራዊ ሩዝ ምርምር ፕሮገራም የሚጠቅሙበትን ሁኔታ መሻት የሚሉ ናቸው። ኤክሱ-ጅግና ከሰሜን ኮሪያ ወደ ኢትዮጵያ በ1980ዎቹ አጋማሽ የገበና በኮሪያዊያን ሳይንቲስቶች ለፎገራ አካባቢ ተላማጅነቱ ተረጋግጦ ወደ ማማረት ሂደት እዲገባ የተደረገ የሩዝ ዝርያ ነው። በ2009 እና 2010 ዓ.ም የተደረገ የሩዝ ዝርያ ስርፀት ጥናት አንዳመለከተው የፎገራ አካባቢ ሩዝ ልማት 81 ፐርሰንት የተሸፈነው በኤክሱ-ጅግና ነው። ዝርያው ምንም እንኳን ለረጅም ጊዜ በማምረት ሂደት የቆዬ ቢሆንም ከፍተኛ ምርታማነት፤ ጥሩ የበሽታ መከላከል አቅም፤ በከፍተኛ ደረጃ በተጠቃሚዎች ተወዳጅነት (በተለይም ደግሞ ነጭ የፍሬ ቀለሙ) ባህሪያትን እያሳዬ ይገኛል። ከዚህ በተጨማሪ አርሶ አደሮች የኤክሱ-ጅግና ዱቄቱ ወፃ ያነሰል እንጀራውም ቶሎ እይደርቅም ብለው ይገልፀታል። በአጠቃላይ አርሶ አደሮች ኤክሱ-ጅግናን አብዛኛውን ተፈላጊ ባህሪያት የያዘ ዝርያ ነው ይላሉ። የሩዝ ብሔራዊ ምርምር ፕሮገራም ከስድስት የሚበልጡ ለፎገራ አካባቢ ተስማሚና ምርታማ የተሻሻሉ የሩዝ ዝርያዎችን ለቋል። ይሁን እንጅ ከዝርያ የስርፀት ጥናት እነደምንረዳው አንዳቸውም ዝርያ ኤክሱ-ጅግናን ሙሉ በሙሉ መተካት አልቻሉም። ብሔራዊ የምርምር ፕሮግራሙ ይህ ለምን እንደ ሆነ ቆም ብሎ ማሰብ ይኖርበታል። ፕሮግራሙ ከተከተለው መንገድና የተለቀቁት ዝርያዎ አነስተኛ ስርፀጽ ከሚያመላክቱት ከፍተኛ አንዱና ዋነኛው የዝርያዎችን ነጠላ ባህሪ ማሻሻልን እንደ ስልት መከተሉ ነው። ለወደፊቱ ፕሮገራሙ ፍላጎት ተኮር እንዲሁም አብዛኛዉን ተፈላጊ ባህሪያት የሚያሟላ ዝርያ ለማውጣት በሚያስችል መልኩ መቃኘት ይኖርበታል።

Abstract

Rice is becoming an enterprise of choice in the Ethiopian farming system. The Fogera plain accounts for 68% of the area and 71% of the production of rice in the country. This paper attempts to explain why a single cultivar called 'X-Jigna' has dominated the lowland rice production portfolio of the Fogera plain in the country for more than 30 years and pinpoints the lessons that these inform to the national rice breeding program. X-Jigna was introduced from North Korea and adopted and recommended by Korean scientists in mid-1980s. Rice adoption study (2016-2017) in the Fogera plain showed more than 81% X-Jigna cultivation. Despite its long time deployment into the production, it has been showing good performance in terms of grain yield, biomass yield with good palatability, good disease reaction, phenotypic acceptability, good tillering capacity, and white caryopsis color. Furthermore, the cultivar has a long and well-exerted panicle, uniform stand, good physical quality, acceptability, and wider utilization. In addition, farmers describe its quality in terms of high flour density 'wuha yanesal' and softness stay of the enjera. Generally, farmers describe X-Jigna as a variety that fulfills most of their important traits. The national breeding program developed at least six lowland rice improved varieties for the Fogera plain to replace X-Jigna. However, the replacement rate of the old

varieties is quite low as evidenced by the high adoption rate and longtime cultivation of X-Jigna. The breeding program needs to stop by and question why this happened and the journey undergone to come here. One of the critical issues that can be learned from the over years of engagement of the breeding program is that it has followed a trait-based improvement approach to deploy new varieties, which led to the low adoption of new varieties. As a way forward, the breeding program has to be demand-driven and product-oriented.

Keywords: *enjera,* Ethiopia, Fogera plain, X-Jigna

Introduction

Rice is a recent introduction to Ethiopia. It has been thought that it was introduced in the early 1970s and its introduction was associated with addressing food security in the country. It was first introduced in Gambella and Pawe areas primarily targeting to support the massive settlers following the 1985 drought and tragic famine it caused (Dawit *et al*., 2018). Abobo and Pawe research centers were established during that time (1985) and aimed at supporting the settlers through provision of adapted technologies including rice. A large scale commercial rice production was successfully operational in those areas particularly in Pawe area by the Italian supported Tana Belles Integrated Development Project. Rice introduction to the Fogera plain, on the other hand, was through a mission of North Korean scientists in mid-1980s (Dawit *et al*., 2018). The scientists' mission was to technically support cooperatives, which were operating in the Fogera area. While working with the cooperatives, the Korean scientists observed wild rice plants in the Fogera plain and hypothesized that the Fogera area could be a potential area for rice production. They continued introducing different rice cultivars from their country, and carried out adaptation trials.

Consequently, the scientists at that time identified and recommended the popular X-Jigna cultivar for the Fogera plain (Tilahun, 2018). The name was given in relation with the village name, *Jigna*, which is one of the villages where the adaptation trial was carried out. As rice was new to the farmers in the area, its cultivation was limited to cooperative member farmers. Even the member farmers were not as such fully convinced to produce rice, and rather its production was imposed by the cooperatives (Dawit *et al*., 2018). Nevertheless, through time the Fogera plain has evolved to be one of the few rice based farming systems in the country. Currently it accounts nearly 68% of rice area coverage and 71% of volume of production of rice in Ethiopia (CSA, 2020). Among other factors that largely contributed to the evolution of the Fogera plain into rice based farming system are: the compatibility of rice cultivation in wetlands of the Fogera plain in which other crops do not grow well; its compatibility with traditional foods mainly tef-rice mixed *enjera;* and the rapid increase in domestic rice consumption. Until

recently, X-Jigna has been the most dominant cultivar with more than 81% adoption rate in this plain (2016/17 rice adoption survey, unpublished). This was how the X-Jigna cultivar has been introduced and promoted into production; and it has since been dominating the rain-fed lowland rice production in the Fogera area.

This paper attempts to present some explanations as to why X-Jigna has dominated the lowland rice production portfolio of the Fogera plain in Ethiopia, and pinpoints the lessons that these inform to the national rice breeding program.

X-Jigna: the Cultivar Profile

The cultivar X-Jigna is japonica-type rice. The morphological and agronomic descriptions of X-Jigna cultivar are summarized on Table 1.

Table 1. Morphological and agronomic description of the rice cultivar X-Jigna

No.	Parameter	Description
1	**Agronomic Characteristics**	
1.1	Adaptation ecology	Lowland
1.2	Days to head (50%)	95-97
1.3	Days to mature (85%)	133-140
1.4	Potential yield (kg/ha)	Research field: 4200-4500 Farmers' field: 3000-3500
1.5	Resistance to lodging	Good
1.6	Resistance to major diseases	Good
1.7	Cold tolerance	Good
2	**Morphological Characteristics**	
2.1	***Plant***	
2.1.1	Average height (cm)	105-110
2.1.2	Number of fertile tillers/plant	Good (7)
2.1.3	Leaf angle	Not-erect
2.1.4	Flag leaf angle	Not-erect
2.2.	***Panicle***	
2.2.1	Type	Intermediate
2.2.2	Length (cm)	22-25
2.2.3	Exertion	Good
2.3	***Caryopsis***	
2.3.1	Color	White
2.3.2	Apex color	Purple
2.3.3	Size	Short
2.3.4	Lemma color	Straw
2.3.5	Thousand grain weight (g)	26
2.3.6	Awning	Absent

Source: Authors' synthesis from historic data

Why Has X-Jigna Been Sustained in the Production for So Long?

The cultivar X-Jigna has still been under production mainly in the Fogera plain since its introduction in the 1980s, and it has been showing good performance in terms of grain yield, biomass yield with good palatability, good disease reaction,

phenotypic acceptability, good tillering capacity, and white caryopsis color (Tables 2 and 3). Furthermore, the cultivar has long and well exerted panicle, short grain size, uniform stand, and exhibits no shattering problem. Based on various historical performance data evaluations (Tables 2-4), it has been evidenced that X-Jigna is highly adapted to the Fogera plain than other lowland ecologies in Ethiopia. The performance of X-Jigna has been consistently higher for many years, and it is still competing with the other recently released varieties in terms of grain yield, and other yield related and farmer-preferred parameters (Table 3). Its white seed color fetches high market price as it is one of the most crucial traits that dictate rice market value in global market, and makes it the most preferred cultivar.

Table 2. Mean grain yield and other yield related parameters of released lowland rice cultivars in Northwest Ethiopia including the Fogera plain (three locations over three years)

Traits	Cultivar			
	Hiber	Ediget	Gumara	X-Jigna
Year of release	2013	2011	1999	1980s*
Days to head	86.2	87.4	93.9	90.1
Days to mature	119.5	119.7	125.2	121.6
Panicle length (cm)	17.8	18.2	20.8	20.1
Plant height (cm)	89.6	97.6	113.0	103.0
No. of fertile tillers/plant	5.4	4.6	6.1	5.4
No. of filled grains/panicle	75.1	93.5	86.7	104.7
Grain yield (kg/ha)	3566.6	3905.6	4276.1	3504.2
Caryopsis colour	White	White	Brown	White

1980s*, X-Jigna was introduced in 1980s, not released variety

Source: Authors' analysis from historical performance data

Table 3. Mean grain yield and other yield related parameters of released lowland rice cultivars in the Fogera plain (three locations over three years)

Cultivar	Days to head	Days to mature	No. of fertile tillers/plant	No. of filled grains/panicle	Grain yield (kg/ha)
Hiber	93.7	120.6	5.7	75.3	4216.5
Ediget	103.9	119.2	4.4	90.5	4698.0
Gumara	97.0	126.9	6.4	91.0	5976.4
X-Jigna	96.3	123.3	5.1	114.9	4468.7

Source: Authors' analysis from historical performance data

Moreover, X-Jigna has got good physical quality, acceptability and wider utilization. This could fairly be confirmed by the wider and sustained acceptance of the cultivar by the farming community as well as by the domestic market. It can be seen from the (CSA, 2020) data that about 71% of the rice production in this country is from the Fogera plain. It can safely be estimated that more than 81% of this produce is from the cultivar X-Jigna (Table 5). In addition, farmers usually mention that the straw of X-Jigna is palatable as livestock feed.

Generally, farmers describe X-Jigna as a variety that fulfills most of the important desirable traits. This is because; X-Jigna is a product that has been profiled with most important and acceptable traits. These include not only agronomic traits but also customer preferences. Another key attribute of the cultivar is its high and palatable biomass, which is crucial to integrate rice production with livestock husbandry. Farmers in the Fogera plain are very critical for this attribute of rice as it has been apparent in many of our interactions with them. Among the other the functional properties that farmers 'love' X-Jigna cultivar is its excellent *enjera* making quality. They usually describe the quality in terms of high flour density '*wuha yanesal*' and softness stay of the *enjera* prepared from this cultivar.

Table 4. Mean grain yield and other yield related parameters of X-Jigna and newly released lowland rice varieties in Northwest Ethiopia (2014-2016)

Parameter	Cultivar			
	Wanzaye	Shaga	Ediget	X-Jigna
Days to head	98.4	90.1	87.4	95.4
Days to mature	125.8	129.0	130.8	132.3
Panicle length (cm)	19.0	18.4	17.4	19.1
Plant height (cm)	97.6	105.3	88.1	97.6
No. of fertile tillers/plant	8.2	7.2	6.1	6.9
No. of filled grains/panicle	79.4	106.1	80.2	94.0
Filled grains/panicle (%)	94.5	93.2	91.4	90.8
Thousand seed weight (g)	34.7	24.3	29.7	25.5
Grain yield (kg/ha)	5166.4	4841.2	3671.4	3637.3
Panicle exertion (cm)	1.7	1.6	4.0	2.1
Phenotypic acceptability	2.8	1.7	4.5	4.0
Panicle blast	1.0	1.1	1.5	1.7
Brown spot	0.1	0.1	0.8	0.8

Source: Authors' analysis from performance data

What Is the Current Status of the Cultivar?

A rice adoption survey conducted in 2016-2017 showed that majority of the farmers in the Fogera plain (82%) have been cultivating X-Jigna (Table 5), and there has still been a continuing consistent request for foundation seed of the cultivar by farmers. Even though the cultivar has been produced since its introduction, it is not yet officially registered in the list of rice varieties in Ethiopian variety registration system. Farmers' request for initial seed is very legitimate to keep the genetic and physical qualities of the cultivar, which is one of the underlying requirements to have sustainable productivity of the cultivar. Nevertheless, farmers' seed of this cultivar has never been rejuvenated since its introduction in 1980s. It has been recommended for cereals including rice that farmers' own saved seed should be replaced after every 3-4 years of selfing (Amsalu and Dawit, 2019). All of these circumstances justify that the cultivar X-Jigna needs to be registered.

An official application for its registration was made to the National Variety Release Committee (NVRC) in 2018. The application was justified based on consistent and stable performance of the cultivar and standard variety verification trial of NVRC in 2018/2019 cropping season. However, its registration was not approved as the NRVC demanded its original nucleus seed from its origin, North Korea. Accessing the nucleus seed is practically impossible as the cultivar was introduced many years ago and its pedigree (identification) is not known. One of the other driving factors for its registration, apart from foundation seed replenishment for genetic purity, is that the cultivar is getting attacked by a disease called sheath rot, which is mainly transmitted through seed. Sheath rot is becoming an important disease in lowland rice production in Ethiopia particularly in the Fogera plain (Tekalign *et al*., 2019). Farmers have developed experience of seed replenishment from a particular area as informal seed source, which on the other hand would aggravate sheath rot infestation because of the seed movement. Seed treatment fungicides for the management of sheath rot were found effective (Muluadam *et al*., 2020). Hence, healthy and treated initial seed of the cultivar has to be injected from known formal seed system to the production system, which, in turn, necessitates registration of the cultivar.

In the last few years, the sheath rot disease pressure on X-Jigna is becoming high and causing significant yield losses (Tekalign *et al*., 2019). Farmers consistently voiced their concern about this biotic constraint and complained that this has posed serious problem on their rice production. An experiment done to evaluate the level of resistance of different genotypes including X-Jigna showed genetic diversity among the genotypes in their reaction to sheath rot; however, X-Jigna found susceptible (Desalegn *et al*., 2020). In response to the farmers' problem, the breeding program developed and deployed different improved rice varieties in the lowland ecology including the Fogera plain. Among these varieties, the recently released variety called 'Shaga' is getting acceptance by the farmers particularly because of high grain and biomass yield, and resistance to sheath rot. However, X-Jigna is still in the farmers' heart, except that it is suffering from sheath rot disease pressure. Shaga (Scrid017-1-4-4-4-1) was released by the functional partnership efforts between the Ethiopian Institute of Agricultural Research and Africa Rice Center through a project called Stress Tolerant Rice for Africa and South Asia (STRASA). The project was funded by Bill and Melinda Gates Foundation.

The Lessons for the National Rice Breeding Program

Formal rice improvement research in Ethiopia was commenced in the 1980s. Since then, 39 improved rice varieties targeting different ecosystems (18 rain-fed upland, 9 rain-fed lowland, 3 cold tolerant, and 9 irrigated) have been released and/or registered (MoA, 2020). The recently released varieties had as high as 5

t/ha of grain yield performance in research managed fields along with the use of all components of the recommended package. However, the replacement rate of old varieties is quite low. This could be evidenced by the high adoption rate and longtime cultivation of X-Jigna, a cultivar which was introduced before 30 years. The question here is, thus, why is it so?

The national breeding program deployed at least six lowland rice improved varieties for the Fogera plain to replace X-Jigna. The first variety was 'Gumara', which was released in 1999 (MoA, 1999). This variety has got high biomass and strong culm, both of which are good traits particularly in the Fogera plain. However, its seed color is brown (not preferred especially in the market), and *enjera* making quality compared to X-Jigna is poor. Its high biomass yield and strong culm make the variety preferred by those farmers who are producing rice in high flooded fields. However, it has only about 13% adoption rates in the Fogera plain (Table 5). The major reasons as mentioned by farmers of this low adoption are its brown seed color and poor *enjera* making quality.

A continued effort by the national breeding program brought another variety called 'Ediget' in 2011 (MoA, 2011). As the major deficiency of Gumara variety was brown seed color, the breeding program considered white seed color as a must-in trait such that the seed color of Ediget is white. The extent of whiteness of this variety is even better than X-Jigna. However, its adoption rate is quite low (5.5%) even lower than Gumara. What happened? It is not because its grain yield performance was inferior to either X-Jigna or Gumara. Interestingly, it has even got additional advantages of earliness and cold tolerance. Rather it is because its biomass yield is low; whilst high biomass is one of a must-in trait particularly in the Fogera plain where livestock feed is mainly dependent on rice straw and bran. In addition, its *enjera* making quality is poor compared to X-Jigna. Another weakness that farmers complained on promotion of Ediget was that it needs more management for emergence and establishment, which implies more cost and farmers' time.

Table 5. Adoption of X-Jigna in the Fogera plain compared to other varieties (2016-2017)

Variety	Area coverage in percentage
X-Jigna	81.69
Gumara	12.76
Ediget	5.55
Total	100.00

Source: Rice survey conducted in 2016-2017 (unpublished)

This situation has pushed the breeding program to advance its efforts; and managed the release of two varieties called 'Shaga' and 'Wanzaye' targeting the Fogera plain including other similar lowland ecosystems in 2017 (MoANR, 2017). These two varieties combined both high grain and biomass yield, resistance to

major rice diseases including sheath rot, and tolerance to cold. However, their seed color is not white. Wanzaye has brown seed color, while Shaga has got near-white seed color but it needs extended polishing that otherwise render one with brown caryopsis color. The varieties have been demonstrated and popularized during the last three cropping seasons in the Fogera plain. Farmers have good impressions and developed interest in producing both varieties. Seed demand particularly for Shaga is increasingly high from the Fogera plain as well as other similar lowland ecologies. However, farmers still have reservations on the seed color of these varieties. So, farmers were asked as to why they accepted these varieties during a focused group discussions made to know farmers' criteria of adoption or dis-adoption of a variety. The high grain and biomass yield, and resistance to sheath rot are the major traits that boosted the varieties to be accepted by the farmers. Parallel to this, productivity of X-Jigna has been decreasing because of the sheath rot disease. They said, that is why we accepted Shaga and Wanzaye, while there have otherwise been no varieties which completely replaced X-Jigna. Thus, farmers' demand is not still completely addressed.

Consequently, we need to stop-by and question the journey we have come up until here. One of the critical issues that we can learn from the over-years' of engagement of the breeding program is that it has followed a trait based improvement approach to deploy new varieties. In this regard, it has been possible that the breeding program ascertained positive genetic gain over the years for some important agronomic traits including grain yield (Abebaw *et al*., 2019). However, it has not been a guarantee for good adoption of those varieties. On the other hand, poor adoption could be a consequence of improper understanding and representation of the target community whom the varieties have been intended to address and benefit. Several case studies on various commodities in sub-Saharan Africa including Ethiopia provided evidence that men and women have different trait preferences, access to resources, or opportunities to engage in production, processing, and marketing of diverse commodities (Tufan *et al*., 2018). Furthermore, the extension system and efforts to promote rice have not been enough. It has been tried to link with the national extension system development as it is for other agricultural commodities, despite the fact that the rice crop is new to Ethiopia and needs a different approach (Assefa, 2012).

Conclusions and the Way Forward

The trait profiles of X-Jigna and its stability over years made the cultivar preferred and produced by the farmers for more than 30 years in the Fogera plain of Ethiopia. Farmers describe the cultivar as near complete variety that fulfills most of their important attributes. The continued efforts of the national breeding program didn't completely replace X-Jigna in the Fogera plain. One critical reason of this, which can be learnt from the over-years' of engagement of the breeding

program is that it has followed a trait based improvement approach to deploy new varieties.

This informs that the breeding program has to be demand-driven and product-oriented (Nasser *et al*., 2017). Proper understanding and characterization of the target production environment and community are very critical (Tufan *et al*., 2018; Mulugeta *et al*., 2019). Employing participatory approaches in the improvement program will also incorporate the knowledge and preferences of farmers and other technology users (Morris and Bellon, 2004). Concomitant to these, thorough characterization of market segments is of decisive factor of importance for a product to be accepted and adopted by the users. Comprehensive analysis of these factors leads to a concept called "product profile". The product profile functions as a contract between all stakeholders in a network to design and deliver market oriented products. Currently, the national breeding program realized the importance of product concepts and attempted to employ it in new national breeding projects via identification of different products to be delivered. A proper breeding pipeline plan to deliver those products is critical and needs to be emphasized.

Among others, replacing the X-Jigna in the Fogera plain is proposed as one important product concept by the national breeding program. As discussed above, X-Jigna has been a product of farmers' choice, but recently affected by sheath rot disease and getting out of production. Hence, the strategy should be improving its sheath rot resistance while keeping all those preferred traits. This could be possible through backcrossing breeding technique. Backcrossing is usually considered to be a strategy suitable mainly for introgression of one or a few disease or insect resistance genes into an elite cultivar (Brar and Khush, 1997). Donor lines for sheath rot resistance have been identified under Fogera condition, and these lines have also exhibited good performance for important agronomic traits including grain and biomass yield although their caryopsis color are not white (Desalegn *et al*., 2020).

In conclusion, the experiences with the oldest variety X-Jigna in the Fogera plain have entailed the need for devising appropriate breeding strategies and approaches that hold considerable promise in the development and release of a replacement for and even better variety than X-Jigna

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