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EARLY-MATURING RICE (*ORYZA SATIVA* L.) ADVANCED LINES ASSESSMENT FOR GRAIN YIELD AND QUALITY CHARACTERISTICS

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SUMMARY

This study aimed to evaluate early-maturing rice (*Oryza sativa* L.) advanced lines for grain yield, grain-quality traits, and stability over three years (2019–2021). Four rice advanced lines (S-7-12, S-106, TSHD 20-13-1-3-1-1, and S-123) and one check cultivar (Guljahon) received assessments for agromorphological traits, milling quality, physicochemical properties (amylose and protein content), and pasting characteristics. The advanced line S-106 consistently revealed the highest grain yield (7.31–7.63 t ha^{-1}), early maturity, higher tillering ability, greater panicle fertility, and increased grain weight per panicle. Furthermore, the said line S-106 also exhibited the optimum milling quality and stable amylose content, supporting its suitability for both production and processing. Separately, the advanced line S-123 exhibited higher protein content and favorable eating-quality traits, while the advanced line TSHD 20-13-1-3-1-1 showed the lowest yield performance and stability. Overall, the advanced line S-106 emerged as the most promising line for varietal release because of its genetic potential for the highest grain yield, desirable grain-quality traits, and stability in performance.

Keywords: Rice (*O. sativa* L.), breeding lines, grain yield, milling quality, amylose content, protein content, pasting properties

Key findings: The rice (*O. sativa* L.) advanced line S-106 consistently achieved the highest grain yield (7.31–7.63 t ha^{-1}) with robust stability and broad adaptability across the three years, which was also in association with its early maturity (104.9–106.5 days), reduced plant height, and high tillering capacity.

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INTRODUCTION

Rice (*Oryza sativa* L.) is one of the major staple crops and a primary source of calories for over half of the world's population (Mohidem *et al*., 2022). It has become essential for food security, especially in Asia (Su *et al*., 2024), and increasingly in other regions such as Central Asia, including Uzbekistan (Tellyaev *et al*., 2021; Sattarov *et al*., 2024; Young *et al*., 2025). Nevertheless, global rice production faces numerous challenges from climate change, unpredictable rainfall, rising temperatures, and declining water resources. Addressing these issues earnestly requires the development of high-yielding rice cultivars resilient to diverse environmental conditions (Khayitov *et al*., 2021).

Early-maturing rice cultivars have attracted considerable attention in the present era as an adaptation strategy to address these production constraints (Akhtar *et al.*, 2015). The early-maturing cultivars can complete their life cycle within a shorter period to avoid terminal drought and heat stress. This trait is especially beneficial in regions with limited irrigation and high evapotranspiration rates (Afroz and Akhtar, 2021). Furthermore, early-maturing cultivars facilitate intensified cropping systems, such as rice-wheat and rice-legume rotations, which enhance the cropping intensity, improve land-use efficiency, and enhance overall productivity (Korres *et al*., 2017).

In advanced stages of breeding programs, rice lines typically have the highest genetic homozygosity, resulting in phenotypic uniformity and stability (Seck *et al.*, 2023). At this point, breeding objectives also transition from selection within segregating populations to the comprehensive evaluation of the advanced lines across multiple environments (Lenaerts *et al.*, 2019). Consequently, yield stability across diverse environments is a critical criterion for varietal selection. Grain-quality traits also gain greater importance due to their direct impact on market value, processing efficiency, and consumer acceptance.

Grain quality in rice is a multifaceted trait influenced by various physical and physicochemical characteristics (Juliano, 1971). Physical attributes include grain size, shape, milling recovery, and head rice yield, and these rice properties are crucial for industrial processing and market classification. Physicochemical properties, such as amylose content, gelatinization temperature, and gel consistency, are also decisive for rice cooking and eating quality. Regional consumer preferences for these traits make grain quality a crucial factor in the adoption of new rice cultivars (Custodio *et al.*, 2019).

With the advances in rice breeding, a persistent trade-off exists between early maturity and grain quality. Early-maturing rice lines often experience grain filling under higher temperatures, which can damage the starch synthesis and deposition. This leads to increased grain chalkiness, reduced translucency, greater grain breakage, and lower head rice recovery. Therefore, the early-maturing rice genotypes frequently display inferior milling and appearance quality compared with medium- and late-maturing cultivars (Yun *et al*., 2015; Sharma and Khanna, 2020). These challenges emphasized the need for breeding strategies that improve the earliness and grain quality.

In light of these challenges, comprehensive evaluation integrating phenotypic performance, yield stability, and grain-quality traits is crucial before recommending advanced breeding lines as new cultivars for commercial cultivation. This approach ensures that new cultivars satisfy both agronomic requirements and market standards. The promising study sought to assess the phenotypic performance, yield stability, and grain-quality traits of several advanced early-maturing rice breeding lines (EMRBLs) adapted to the agro-climatic conditions of Uzbekistan.

MATERIALS AND METHODS

Experimental site and weather conditions

The concerned study on rice (*O. sativa* L.) began from 2019 to 2021 at the Rice Research Institute, Uzbekistan. The experimental plot has its location in the southeastern part of Tashkent Region, Uzbekistan (41°11′16″ N and 69°20′07″ E GMT). The experimental site soil was meadow-marshy, non-saline, and neutral (pH: 6.8–7.1). Before rice, the previous crop was soybeans. Before the said experiment, the examined soil parameters were as follows: organic matter content (1.02%), nitrogen content (22.31 mg kg^{-1}), phosphorus content (59.2 mg kg^{-1}), and potassium content (158 mg kg^{-1}). Over the three years of research, the average daily temperature was 14.9 °C–33.4 °C in 2019, 8.2 °C–32.0 °C in 2020, and 10.4 °C–32.4 °C in 2021. The highest temperature appeared on July 24, 2019 (33.4 °C), July 27, 2020 (32.0 °C), and June 27, 2021 (32.4 °C). Relative humidity was 39%–65%, 29%–68%, and 41%–61% in 2019, 2020, and 2021, respectively (Figure 1).

Plant materials

In the field experiments, four early-maturing rice breeding lines (EMRBLs) (S-7-12, S-106, TSHD 20-13-1-3-1-1, and S-123) underwent studies in comparison with the check cultivar Guljahon.

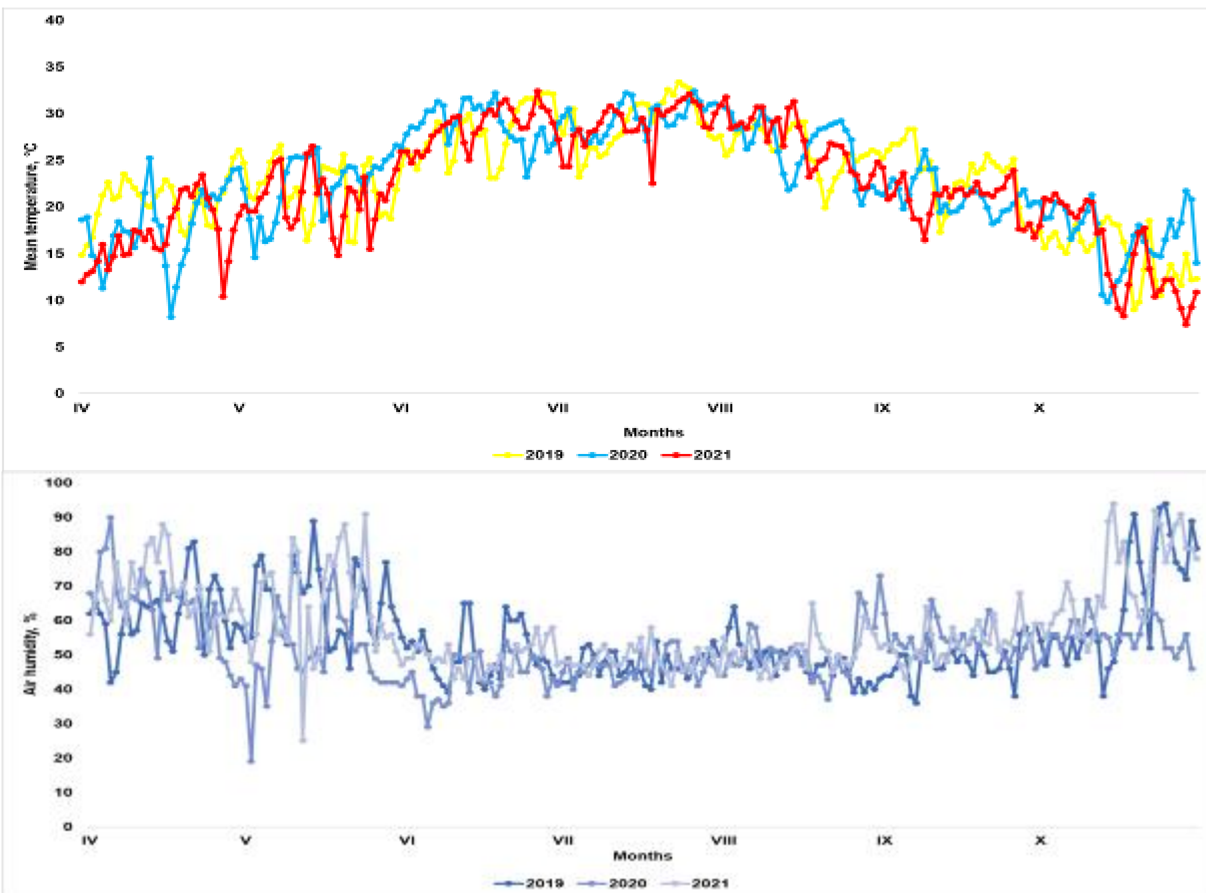

Figure 1. Climate conditions during 2019–2021 in Tashkent Region, Uzbekistan.

Analytical procedure

Representative paddy samples (100 g) proceeded with the collection from each EMRBL and milled rice using a paddy quality test machine (CRM 125-2T, Yaşar Machine, Türkiye). Milling duration and pressure remained constant for all samples. All the conducted measurements were in triplicate, with final mean values used for statistical analysis.

The milled rice (MR), as determined, used the following formula:

$$\text{MR (\%)} = \frac{\text{Weight of milled rice}}{\text{Weight of paddy}} * 100$$

The head rice recovery (HRR) calculation was as follows:

$$\text{HRR (\%)} = \frac{\text{Weight of head rice}}{\text{Weight of paddy}} * 100$$

The EMRBL seeds sustained measurements for grain length and width and length-to-width ratio using the optical seed analyzer (YP-KZ02, Youyunpu Photoelectric Technology, China).

Determination of amylose and protein contents and pasting properties

Amylose content determination used the colorimetric iodine-binding method, as described by Juliano (1971). Protein content, when measured, utilized the Kjeldahl method, following AOAC International (Association of Agricultural Chemists) procedures. The pasting properties of rice flour entailed measuring using a Rapid Visco Analyzer (RVA, Perten Instruments, Sweden). The following RVA parameters obtained automatic recording: peak viscosity (cP), trough viscosity (cP), breakdown viscosity (cP), final viscosity (cP), setback viscosity (cP), pasting temperature (°C), and peak time (min).

RESULTS AND DISCUSSION

Morpho-biological traits

The presented studies on rice (*O. sativa* L.) took place in the variety selection test nursery during 2019–2021, which showed the following morpho-biological indicators of EMRBLs: vegetation day (VG), seedling density (SDen), plant height (PH), tillering rate (TR), and panicle length (PL), differing to a certain extent by year (Table 1).

The results revealed varied values of VG in EMRBLs over the three years. In the check cultivar Guljahan, the VG was 113.5 days in 2019, but in 2020 it increased to 114.1 days, and in 2021, it again decreased to 112.9 days. This implied that the rice plant's growth and development processes slowed down in 2020 and 2021 because of the relatively favorable environmental conditions. The same trend was evident in most EMRBLs, confirming the years' effect (Table 2). In the advanced line S-106, the VG was significantly shorter than the check cultivar during the three years of study, which was 105.2 days in 2019, 104.9 days in 2020, and 106.5 days in 2021. Nonsignificant differences existed among the study years, which allows us to characterize this line as a stable line for early maturity. In the remaining three EMRBLs—S-7-12, TSHD 20-13-1-3-1-1, and S-123—the VG was at par with the check cultivar for the years, with a tendency to lengthen, as observed in 2020. Previous research revealed that rice earliness had the influence of both genotypes and environmental conditions (Jambhulkar *et al.*, 2019; Mongiano *et al.*, 2020).

By analyzing the SDen by years, relatively high values resulted in all the EMRBLs in 2019, a decrease in some lines in 2020, and a tendency to increase again in 2021. In the check cultivar Guljahon, the SDen was 139.1 seedlings/m² in 2019, but decreased to 131.2 seedlings/m² in 2020 and increased again to 140.1 seedlings/m² in 2021.

Table 1. Morphobiological and agronomic traits of the EMRBLs in the rice variety selection trial nursery during 2019–2021.

EMRBLs	Vegetation day (days)	Seedling density (s/m²)	Plant height (cm)	Tillering rate	Panicle length (cm)	1000-grain weight (g)	Panicle fertility (%)	Panicle sterility (%)	Grain weight panicle^{-1} (g)
2019									
Guljahon (check)	113.5±3.2	139.1±3.2	127.6±4.1	1.85±0.11	21.8±0.6	32.7±0.27	85.0±0.7	15.0±0.71	3.17±0.12
S-7-12	114.2±2.8	144.5±2.8	127.4±3.9	1.82±0.12	21.1±0.7	32.1±0.28	87.2±0.7	12.8±0.72	3.09±0.14
S-106	105.2±2.8	138.4±2.8	118.9±3.9	1.88±0.11	20.8±0.7	32.7±0.23	87.6±0.7	12.4±0.60	3.19±0.12
TSHD 20-13-1-3-1-1	114.7±2.9	162.1±2.9	124.5±4.0	1.67±0.11	20.2±0.6	32.2±0.27	84.7±0.8	15.3±0.70	2.99±0.14
S-123	109.2±3.0	152.2±3.0	125.8±4.0	1.84±0.12	20.0±0.6	32.5±0.26	84.5±0.7	15.5±0.68	2.87±0.13
$LSD_{0.05}$	8.33	8.41	11.28	0.32	1.81	0.75	1.98	1.95	0.38
2020									
Guljahon (check)	114.1±3.1	131.2±3.1	129.6±3.8	1.91±0.12	22.0±0.7	33.0±0.27	85.9±0.7	14.1±0.75	3.20±0.13
S-7-12	113.0±2.9	142.1±2.9	126.1±4.0	1.77±0.13	20.8±0.6	32.3±0.27	87.8±0.7	12.2±0.73	3.19±0.13
S-106	104.9±2.9	132.4±2.9	117.7±3.8	1.93±0.12	21.1±0.7	32.9±0.25	87.7±0.7	12.3±0.62	3.21±0.13
TSHD 20-13-1-3-1-1	113.4±3.0	148.4±3.0	124.0±4.0	1.78±0.11	20.7±0.6	32.1±0.26	85.3±0.8	14.7±0.72	3.00±0.13
S-123	108.7±3.2	148.7±3.2	124.6±3.9	1.75±0.13	20.8±0.7	32.6±0.25	85.4±0.7	14.6±0.72	3.03±0.13
$LSD_{0.05}$	8.65	8.55	11.15	0.35	1.85	0.73	1.95	1.98	0.36
2021									
Guljahon (check)	112.9±3.2	140.1±3.2	126.9±3.9	1.82±0.10	21.5±0.6	32.8±0.26	85.7±0.8	14.3±0.62	3.23±0.12
S-7-12	113.6±2.9	137.6±3.2	125.5±3.8	1.83±0.11	21.4±0.7	32.5±0.26	87.4±0.7	12.6±0.72	3.25±0.14
S-106	106.5±2.9	140.7±3.1	116.9±3.8	1.86±0.11	21.0±0.7	32.9±0.24	88.5±0.7	11.5±0.72	3.28±0.11
TSHD 20-13-1-3-1-1	112.6±2.8	146.1±3.0	123.1±4.0	1.77±0.10	21.1±0.6	32.4±0.24	86.2±0.8	13.8±0.70	3.07±0.13
S-123	111.1±2.9	142.5±3.2	126.7±4.0	1.86±0.11	20.9±0.6	32.7±0.25	85.5±0.7	14.5±0.70	3.07±0.13
$LSD_{0.05}$	8.45	8.87	11.11	0.3	1.8	0.71	1.97	1.95	0.35

Table 2. List of early-maturing rice breeding lines (EMRBLs).

EMRBLs	Cross combinations	Origin
Guljahon (check)	Naylamp/UzROS7-13	*O. sativa* L. ssp. japonica
S-7-12	F_9Ilgor/Istiklol	*O. sativa* L. ssp. japonica
S-106	F_7Marvarid/Vikant	*O. sativa* L. ssp. japonica
TSHD 20-13-1-3-1-1	F_8Istiklol/1977-94	*O. sativa* L. ssp. japonica
S-123	$F_7$205-01/Iskandar	*O. sativa* L. ssp. japonica

The advanced line TSHD 20-13-1-3-1-1 showed distinction by the higher seedling density than the check cultivar in all study years, and this indicator had the range of 146–162 seedlings/m². Previous studies have shown that increasing seedling density considerably enhanced the panicle number per unit area but may reduce the number of spikelets per panicle because of increased intra-specific competition among the plants (Tian *et al*., 2023; Gai *et al*., 2025).

Plant height is an important determinant of yield potential, and the genotypes with reduced height enhance lodging resistance and minimize yield losses. Consistent with this, reports of a negative correlation between plant height and grain yield have occurred in past studies (Breseghello *et al*., 2011; Pereira-de-Castro *et al*., 2023). Plant height in most EMRBLs increased slightly in 2020 but decreased in 2021. For the check cultivar, the plant height was 127.6 cm in 2019, increased to 129.6 cm in 2020, and decreased to 126.9 cm in 2021. In the advanced line S-106, the plant height was lower than that of the check cultivar in all years, which was a considerable positive characteristic, increasing its lodging resistance.

Agronomic traits

The 1000-grain weight (TGW) remained relatively stable over the years, and the year-specific influence was less pronounced compared with other traits (Table 2). These results were consistent with previous rice studies (Al-Salim *et al*., 2016; Feng *et al*., 2023). In the advanced line C-106, TGW remained at 32.7–32.9 g during the three years of study. Similarly, in the check cultivar, the TGW values ranged from 32.7 to 33.0 g during 2019–2021.

In 2021, the recorded highest panicle fertility (PF) emerged in all the studied rice lines. In the advanced line S-106, the PF was 87.6% in 2019, 87.7% in 2020, and 88.5% in 2021. This trend enunciated the gradual improvement in grain quality from year to year. However, the proportion of panicle sterility (PS) decreased accordingly, with 2021 emerging as the most favorable year.

Grain weight per panicle (GWpp) showed an obvious trend across the years. In the advanced line S-7-12, GWpp was 3.09 g in 2019, 3.19 g in 2020, and 3.25 g in 2021. In the line S-106, GWpp was 3.19 g in 2019, 3.21 g in 2020, and 3.28 g in 2021. However, the highest values appeared during 2021. A similar trend resulted in the rice check cultivar. The study year 2020 was relatively unfavorable for many traits, while 2021 proved to be the most favorable.

Grain yield

Most studies have demonstrated significant long-term improvement in grain yield; however, by phase-wise examination of breeding programs, the genetic gain in grain yield revealed variable and sometimes inconsistent trends (Venkatanagappa *et al*., 2021; Khanna *et al*., 2022). For grain yield, significant ($p \leq 0.05$) differences were evident among rice lines across the three years of study (2019–2021). The results enunciated substantial genetic variability and a pronounced lines by year interaction (Figure 2). Overall, the grain yield ranged from 7.16 to 7.39 t ha^{-1} during 2019. The advanced line S-106 achieved the highest yield (7.39 t ha^{-1}), significantly outperforming all other lines and the check cultivar. The standard cultivar Guljahon (7.26 t ha^{-1}) and the line S-7-12 (7.23 t ha^{-1}) revealed intermediate performance, whereas the line S-123 (7.16 t ha^{-1}) recorded the lowest grain yield.

A similar trend was notable in 2020, and the advanced line S-106 maintained the highest grain yield (7.31 t ha^{-1}). Advanced lines TSHD 20-13-1-3-1-1 and S-123 produced considerably minimum yields (7.06 and 7.01 t ha^{-1}, respectively), indicating reduced productivity under the study conditions. In 2021, the line S-106 again exhibited a leading performance, achieving the highest yield (7.63 t ha^{-1}), and confirmed its stability and adaptability. The check cultivar Guljahon and the line S-7-12 displayed moderate grain yields (7.27–7.33 t ha^{-1}), while the advanced line S-123 continued to record the lowest grain yield. The consistent superiority of the line S-106 across all the study years detailed the highest

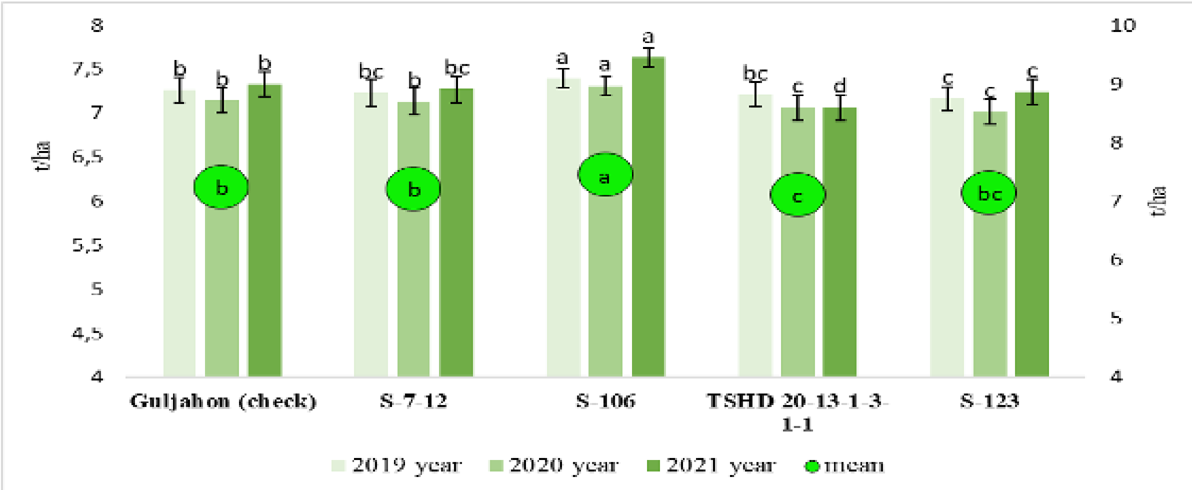

Figure 2. Yield of early-maturing rice (*O. sativa* L.) advanced lines during 2019–2021.

yield stability and adaptability to varying environmental conditions. In contrast, advanced lines TSHD 20-13-1-3-1-1 and S-123 demonstrated lower and less stable performance, revealing limited suitability for high-yield production systems.

Milling quality traits

Milling quality is an essential aspect of rice germplasm characterization (Zhao *et al.,* 2015). In the studied rice genotypes, the milled rice rate (MRR) ranged from 68.1% to 70.7%. The advanced line S-106 and the check cultivar Guljahon showed the highest values (70.6%), while lines TSHD 20-13-1-3-1-1 and S-7-12 were noticeably the lowest rates (68.7%–68.8%) (Table 3). This pattern remained stable across years, and the line S-106 was consistently leading (70.2%–70.7%).

Head rice recovery (HRR), the key indicator of milling quality, varied from 85.0% to 87.2% in the studied rice genotypes. The advanced line S-106 and the check cultivar Guljahon had the highest HRR values (87.2%), whereas line TSHD 20-13-1-3-1-1 consistently showed the lowest values (85.0%–85.3%). Overall, the advanced line S-106 exhibited superior and stable milling performance, while the line TSHD 20-13-1-3-1-1 expressed the lowest efficiency.

Grain physical traits

Overall, in the rice genotypes, the grain length ranged from 7.95 to 8.69 mm. The check cultivar Guljahon and the advanced line S-106 had the longer grains (> 8.5 mm), while the line TSHD 20-13-1-3-1-1 emerged with the shortest grains (7.95–8.01 mm). In rice genotypes, grain width varied from 2.87 to 3.21 mm, with the highest values in the check cultivar Guljahon and the lowest in the line S-123. The length-to-width ratio (L/W) is an influential indicator of grain shape and market preference. In rice genotypes, the L/W values (2.64–2.94) indicate medium-to-slender types of grains. The advanced line S-123 showed the slenderest grains (2.81–2.94), whereas the line TSHD 20-13-1-3-1-1 had the more rounded-shaped grains (2.64–2.73).

Amylose content

Amylose content (AC) is a critical determinant of the cooking and eating quality of rice. High AC proved to have an association with grains that were firm and non-sticky after cooking, whereas low AC results in a softer and stickier texture in rice (Jawaria *et al.,* 2023). In the studied rice lines, the AC ranged from 19.33% to 21.10%, enunciating that all the lines belonged to the intermediate amylose group,

Table 3. Milling and physical grain quality traits of early-maturing rice (*O. sativa* L.) advanced lines during 2019–2021.

EMRBLs	Milled rice rate (%)	Head rice recovery (%)	Grain length (mm)	Grain width (mm)	length-to-width ratio
2019					
Guljahon (check)	70.1±0.25	86.9±0.24	8.69±0.13	3.14±0.05	2.77±0.05
S-7-12	68.8±0.24	86.0±0.22	8.39±0.13	3.07±0.08	2.73±0.06
S-106	70.6±0.23	87.0±0.22	8.68±0.12	3.02±0.08	2.87±0.06
TSHD 20-13-1-3-1-1	68.7±0.30	85.3±0.25	7.98±0.15	2.92±0.07	2.73±0.07
S-123	69.8±0.29	85.9±0.22	8.41±0.14	2.99±0.07	2.81±0.06
$LSD_{0.05}$	0.78	0.69	0.41	0.21	0.18
2020					
Guljahon (check)	69.7±0,.26	86.7±0.23	8.60±0.12	3.21±0.06	2.68±0.05
S-7-12	68.4±0.24	86.1±0.22	8,.41±0.14	3.15±0.07	2.67±0.07
S-106	70.2±0.23	86.4±0.23	8.50±0.13	3.11±0.07	2.73±0.05
TSHD 20-13-1-3-1-1	68.1±0.25	85.0±0.24	8.01±0.15	3.03±0.07	2.64±0.06
S-123	69.2±0.24	85.7±0.24	8.40±0.13	2.91±0.08	2.89±0.05
$LSD_{0.05}$	0.73	0.71	0.39	0.22	0.17
2021					
Guljahon (check)	70.4±0.25	86.1±0.24	8.55±0.13	3.17±0.06	2.70±0.05
S-7-12	69.1±0.25	86.4±0.24	8.38±0.14	3.05±0.07	2.75±0.07
S-106	70.7±0.24	87.2±0.23	8.52±0.14	3.14±0.07	2.71±0.06
TSHD 20-13-1-3-1-1	68.2±0.25	85.0±0.24	7.95±0.15	3.01±0.07	2.64±0.07
S-123	69.6±0.26	85.2±0.24	8.43±0.14	2.87±0.07	2.94±0.07
$LSD_{0.05}$	0.75	0.72	0.42	0.21	0.19

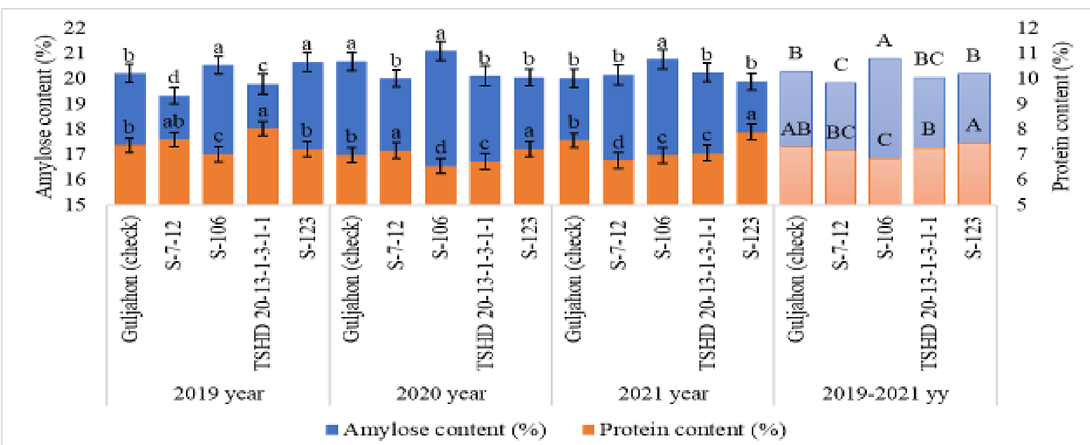

Figure 3. Cooking and nutritional quality of early-maturing rice (*O. sativa* L.) advanced lines during 2019–2021.

which is a general preference for balanced cooking and eating quality (Figure 3). In 2019, lines S-123 (20.66%) and S-106 (20.54%) exhibited the highest AC, while line S-7-12 appeared with the lowest AC value (19.33%). For 2020, the advanced line S-106 emerged with the maximum AC (21.10%), significantly higher than other lines. This trend also continued in 2021, and the line S-106 maintained the highest value (20.77%).

Over the 2019–2021 years, the advanced line S-106 consistently exhibited the highest average AC (20.8%), followed by the check cultivar Guljahon (20.31%) and line S-

123 (20.2%). In contrast, the line S-7-12 exhibited the lowest average value (19.83%). The relatively stable AC observed in the line S-106 suggested its suitability for breeding programs that aim to achieve the consistently desirable cooking quality.

Protein content

Protein content significantly varied among the advanced lines and study years, ranging from 6.55% to 8.02%. In 2019, the highest protein content resulted in the line TSHD 20-13-1-3-1-1 (8.02%), while the line S-106 showed the lowest value (7.01%). For the year 2020, lines S-123 and S-7-12 exhibited the highest protein levels (7.21% and 7.15%, respectively), whereas line S-106 again showed the lowest protein value (6.55%). In 2021, the line S-123 gave the highest protein content (7.88%), significantly exceeding other rice lines. Over the three-year average, the advanced line S-123 maintained the highest protein content (7.44%), followed by the check cultivar Guljahon (7.30%) and line TSHD 20-13-1-3-1-1 (7.27%). The advanced line S-106 consistently had the lowest protein content (6.84%).

According to physicochemical properties, an inverse relationship was evident between the amylose and protein content among the studied rice lines. Advanced lines with higher amylose content, such as S-106, tended to have lower protein levels, while other lines with higher protein content (S-123 and TSHD 20-13-1-3-1-1) exhibited relatively moderate amylose values. These results were greatly analogous to previous findings on rice quality traits (Juliano *et al.,* 1972; Qian *et al.,* 2026).

Pasting properties

Among the rice lines, the peak viscosity ranged from 203.00 to 249.25 RVU, with the highest values observed in the check cultivar Guljahon (248.83 RVU) and line S-123 (249.25 RVU). Meanwhile, the lowest value occurred in line S-106 (203.00 RVU), indicating reduced starch swelling. Higher viscosity signified being in association with better water absorption and cooking quality (Table 4). The HPV ranged from 129.67 to 166.34 RVU, and the line S-106 showed the lowest value (129.67 RVU), while the rice check cultivar Guljahon and lines S-7-12, TSHD 20-13-1-3-1-1, and S-123 expressed the higher and stable values (163.00–166.34 RVU).

The breakdown viscosity (BDV) varied from 73.33 to 86.25 RVU among the rice lines, with the highest being in line S-123 (86.25 RVU), while the lowest was in line S-106 (73.33 RVU). It reflected maximum breakdown susceptibility at the higher values. Final viscosity (CPV) ranged from 228.58 to 268.24 RVU, and Guljahon showed the highest CPV (268.24 RVU), followed by advanced lines S-7-12 and TSHD 20-13-1-3-1-1, while S-106 had the lowest value (228.58 RVU).

Table 4. Pasting properties of early-maturing rice (*O. sativa* L.) advanced breeding lines. PKV (Peak viscosity), HPV (Trough viscosity), BDV (Breakdown viscosity), CPV (Final viscosity), SBV (Setback viscosity), PeT (peak time, min), and PaT (pasting temperature, t °C).

Properties	Guljahon (check)	S-7-12	S-106	TSHD 20-13-1-3-1-1	S-123	$LSD_{0.05}$
PKV (RVU)	248.83	247.58	203.00	246.22	249.25	4.25
HPV (RVU)	165.67	165.50	129.67	166.34	163.00	3.18
BDV (RVU)	83.17	82.08	73.33	79.88	86.25	2.44
CPV (RVU)	268.24	266.17	228.58	266.17	264.25	4.10
SBV (RVU)	19.41	18.58	25.58	19.95	15.00	1.95
PeT (Min)	6.3	6.30	6.30	6.30	6.30	
PaT (t °C)	72.9	75.30	71.30	75.30	73.60	0.85

The setback viscosity (SBV) ranged from 15.00 to 25.58 RVU among the rice lines, with the highest value observed in line S-106 (25.58 RVU), indicating greater retrogradation, while the lowest was in line S-123 (15.00 RVU), suggesting better eating quality. Peak time was constant at 6.3 min across all the rice lines, showing the same gelatinization rates. The pasting temperature ranged from 71.3 °C to 75.3 °C, and highest was in lines S-7-12 and TSHD 20-13-1-3-1-1 (75.3°C), while the lowest was in line S-106 (71.3°C), indicating earlier gelatinization. Overall, the advanced rice line S-123 showed the best balance of high peak viscosity and low setback, revealing superior grain cooking quality, while the line S-106 showed inferior pasting properties and firmer texture after cooking.

CONCLUSIONS

This study identified substantial genetic variability among the EMRBLs according to grain yield, grain quality, and physicochemical properties. Among the evaluated rice (*O. sativa* L.) advanced lines, S-106 consistently achieved leading grain yield, favorable milling qualities, and stable amylose content, support its suitability for both production and processing. The combination of early maturity, high tillering capacity, increased panicle fertility, and enhanced grain weight per panicle contributed to its elevated productivity. The results emphasized the necessity of integrating agronomic, technological, and physicochemical parameters in lines' selection for rice breeding programs. Overall, the study recommends line S-106 as a promising candidate for varietal release and large-scale cultivation under comparable agroecological conditions.

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