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Gujarat Amaranth 6 (SKNA 401): Development, multi-environment evaluation and characterization of a grain amaranth (*Amaranthus hypochondriacus* L.) variety

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ABSTRACT

Grain amaranth (*Amaranthus* spp.) is a nutritionally important pseudo cereal with considerable potential for enhancing food and nutritional security. The present study reports the development, multi-environment evaluation and biochemical characterization of SKNA 401, subsequently identified as Gujarat Amaranth 6 (GA 6). The genotype was developed through pure-line selection and evaluated over a ten year period (2008-09 to 2017-18) under state varietal trials and the All India Coordinated Research Project (AICRP) on Potential Crops. Across state level evaluations, SKNA 401 recorded an overall mean grain yield of 1884 kg/ha, representing yield advantages of 10.37% and 10.82% over the local check GA 3 and the national check GA 2, respectively. Under Gujarat agroecological conditions in AICRP trials, the genotype outperformed the national checks GA 2, Suvarna, BGA-2 and RMA-7. SKNA 401 exhibited desirable agronomic characteristics, including early maturity, reduced plant height and an erect mono stem growth habit. The genotype also recorded higher protein (11.52%) and lysine (8.58 g/100 g protein) contents than the check varieties, along with satisfactory field tolerance to the major diseases and insect pests encountered during the evaluation period. The results demonstrate that SKNA 401 is a high-yielding and nutritionally superior grain amaranth variety suitable for cultivation under the agro-climatic conditions of Gujarat.

Keywords: Grain yield, multi-environment evaluation, pure-line selection, grain quality, lysine, varietal development.

INTRODUCTION

Grain amaranth (*Amaranthus* spp.) is an underutilized C₄ pseudocereal recognized for its high nutritional value and remarkable adaptability to diverse agro-climatic conditions. The grain is an excellent source of high-quality protein with a favourable lysine-rich amino acid profile and contains appreciable amounts of dietary fibre, minerals, vitamins and bioactive compounds (Caselato-Sousa and Amaya-Farfan, 2012; Rivero-Meza *et al.*, 2023). Its C₄ photosynthetic pathway enables efficient carbon fixation under high temperature, intense solar radiation and limited moisture conditions, making it suitable for cultivation in marginal and stress-prone environments (Stetter *et al.*, 2018). In addition, its gluten-free nature and functional properties have increased its importance as a nutritious food crop and

attracted growing scientific and commercial interest worldwide (Caselato-Sousa and Amaya-Farfan, 2012; Stetter *et al.*, 2018).

In India, grain amaranth is cultivated in several states, including Gujarat, Rajasthan, Uttarakhand, Himachal Pradesh, Maharashtra and parts of the North-Eastern region, where it contributes to food and nutritional security (Joshi *et al.*, 2018; Stetter *et al.*, 2018). In Gujarat, where it is commonly known as rajgira, the crop is mainly grown during the *rabi* season and is widely consumed as flour, popped grain and confectionery products. Despite its nutritional and agronomic advantages, grain amaranth remains underexploited, highlighting the need for the development of improved cultivars with higher grain yield, early maturity, lodging resistance and superior grain quality (Joshi *et al.*, 2018; Stetter *et al.*, 2018). Comprehensive

evaluation of agronomic performance, grain yield and grain quality is essential for identifying superior grain amaranth genotypes suitable for varietal development.

Therefore, the present study was undertaken to evaluate the agronomic performance, grain yield and biochemical quality of the promising grain amaranth genotype SKNA 401. The study aimed to generate comprehensive evidence on its performance and assess its potential for varietal development and cultivation under Gujarat conditions.

MATERIALS AND METHODS

Plant material and breeding method

The grain amaranth genotype SKNA 401 was developed through pure-line selection from a locally adapted germplasm maintained at the Centre for Crop Improvement, Sardarkrushinagar Dantiwada Agricultural University (SDAU), Sardarkrushinagar, Gujarat, India. A superior individual plant was selected based on desirable agronomic attributes and advanced through successive generations of progeny selection to achieve genetic uniformity and stability before its evaluation in comparative varietal trials.

Multi-environment evaluation

The performance of SKNA 401 was assessed over a ten year period (2008-09 to 2017-18) through a series of state and national coordinated varietal trials. At the state level, the genotype was evaluated in the State Seed Varietal Trials (SSVT) during 2008-09 to 2011-12 at the Centre for Crop Improvement, SDAU, Sardarkrushinagar. Subsequently, it was evaluated in the Large Scale Varietal Trials (LSVT) during 2015-16 to 2017-18 at four locations in Gujarat, namely Sardarkrushinagar, Ladol, Kholwada and Aseda.

At the national level, SKNA 401 was evaluated under the All India Coordinated Research Project (AICRP) on Potential Crops in the Initial Varietal Trial (IVT) during 2012-13 and the Advanced Varietal Trial-I (AVT-I) during 2014-15 across seven locations representing diverse agro-climatic regions of India, viz., Sardarkrushinagar (Gujarat), Mandor (Rajasthan), Rahuri (Maharashtra), Ambikapur (Chhattisgarh), Bhubaneswar (Odisha), Delhi and Ranchi (Jharkhand).

The genotype was compared with the local check GA 3 and the national check GA 2 in the state trials, whereas under the AICRP trials it was evaluated against GA 2 together with the national checks Suvarna, BGA-2 and RMA-7. All experiments were conducted in a randomized block design with three replications following the standard experimental protocols prescribed under the AICRP on Potential Crops.

Crop management and recording of observations

The crop was grown under irrigated *rabi* conditions using a

spacing of 45 cm × 10-15 cm, a seed rate of 1.5 kg/ha and the recommended fertilizer dose of 60:40:0 kg N:P₂O₅:K₂O. All recommended agronomic and crop protection practices were adopted uniformly across experimental sites.

Observations were recorded on grain yield, plant height, days to 50% flowering, days to maturity, inflorescence length, inflorescence girth, straw yield and test weight following the standard descriptors for grain amaranth. The incidence of major diseases and insect pests was monitored under natural field conditions throughout the crop growth period.

Biochemical analysis

Grain samples of SKNA 401 and the check varieties were analysed at the Central Instrumentation Laboratory, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, for protein, oil, iron, zinc, copper, manganese and lysine contents using standard analytical procedures.

Statistical analysis

The experimental data were subjected to analysis of variance (ANOVA) appropriate for a randomized block design. Mean grain yield, standard error of the mean [S.E.m. (±)], critical difference (CD) at the 5% probability level and coefficient of variation (CV%) were computed following the standard statistical procedures adopted under the AICRP on Potential Crops. The percentage superiority of SKNA 401 over the respective check varieties was estimated based on pooled mean grain yield across environments.

Results and discussion

Grain yield performance in state trials

The grain yield performance of SKNA 401 was evaluated under the State Seed Varietal Trial (SSVT) and Large Scale Varietal Trial (LSVT) during 2008-09 to 2017-18 (Table 1). Across all state level evaluations, SKNA 401 recorded an overall mean grain yield of 1884 kg/ha, compared with 1707 kg/ha for the local check GA 3 and 1700 kg/ha for the national check GA 2, representing yield advantages of 10.37% and 10.82%, respectively. On a weighted mean basis, SKNA 401 recorded a grain yield of 1912 kg/ha, exceeding GA 3 and GA 2 by 12.01% and 11.68%, respectively.

The superiority of SKNA 401 was evident in 13 of the 15 triallocation combinations evaluated, indicating its consistent yield performance across diverse environments. The sustained superiority over both, the local and national check varieties demonstrate the high yield potential and broad adaptability of SKNA 401 under the agro-climatic conditions of Gujarat.

Table 1 : Grain yield performance of SKNA 401 compared with the check varieties GA 3 and GA 2 in State Seed Varietal Trial (SSVT) and Large Scale Varietal Trial (LSVT) conducted in Gujarat during 2008-09 to 2017-18.

Trial	Year	SKNA 401 (kg/ha)	GA 3 – LC (kg/ha)	GA 2 – NC (kg/ha)	% inc. over GA 3	% inc. over GA 2
SSVT	2008-09 to 2011-12	1781 (mean)	1698	14.52	—	—
LSVT	2015-16 to 2017-18	1989 (mean)	1781	18.21	—	—
Overall mean	2008-09 to 2017-18	1884	1707	1700	10.37	10.82
Weighted mean	2008-09 to 2017-18	1912	1707	1712	12.01	11.68
Frequency of superiority	—	13 / 15	—	—	—	—

Source: Compiled from institutional trial records, Centre for Crop Improvement, SDAU, Sardarkrushinagar. LC = local check; NC = national check

Grain yield performance in AICRP trials

The grain yield performance of SKNA 401 was evaluated under the All India Coordinated Research Project (AICRP) on Potential Crops through the Initial Varietal Trial (IVT; 2012-13) and the Advanced Varietal Trial-I (AVT-I; 2014-15) across seven locations representing diverse agro-climatic regions of India. Across all test locations, SKNA 401 recorded an overall mean grain yield of 1134 kg/ha.

When the analysis was restricted to the Gujarat location, SKNA 401 recorded a mean grain yield of 1699 kg/ha, which exceeded the national checks GA 2, Suvarna, BGA-2 and RMA-7 by 5.07%, 38.36%, 14.48% and 11.05%, respectively (Table 2). The superior performance of SKNA 401 under Gujarat conditions, together with its consistent yield advantage in the state varietal trials, indicates its suitability for cultivation in the grain amaranth-growing regions of Gujarat.

Table 2. Mean grain yield performance of SKNA 401 (GA 6) against national checks in AICRP trials within Gujarat

Sr. No	Trial	Mean yield in Gujarat (kg/ha)	% increase over check
1.	GA 2 (national check)	1617	5.07
2.	Suvarna	1228	38.36
3.	BGA-2	1484	14.48
4.	RMA-7	1530	11.05
5.	SKNA 401	1699	-

Agronomic and morphological characteristics

SKNA 401 exhibited distinct agronomic and morphological characteristics that differentiated it from the check varieties (Table 3). The genotype possessed an erect, monostem growth habit with light-green foliage, stem and inflorescence throughout the crop growth period, whereas GA 3 exhibited light pink to light red pigmentation and GA 2 was characterized by red foliage.

SKNA 401 attained 50% flowering in an average of 54 days (range: 43-65 days) and reached physiological maturity in

105 days (range: 88-117 days), indicating earlier maturity than GA 2 (110 days) and comparable maturity to GA 3 (106 days). The mean plant height of SKNA 401 was 143.3 cm (range: 112.0-172.0 cm), which was lower than that of GA 3 (152.6 -160.7 cm) and GA 2 (169.1-178.2 cm). The genotype recorded a test weight of 8.06 g/10 ml, which was marginally higher than that of GA 3 (8.03 g/10 ml) and GA 2 (8.02 g/10 ml). The grains of SKNA 401 were light creamy-white in colour, whereas the check varieties produced creamy-white grains.

Table 3 : Characteristic features of SKNA 401 with checks

Sr. No	Character	SKNA 401	GA 3 (local check)	GA 2 (national check)
1.	Plant type	Erect, monostem	Erect, monostem	Erect, 1-2 branches
2.	Foliage / stem / inflorescence colour	Light green	Light pink / light red	Red
3.	Days to 50% flowering (mean)	54	50	53
4.	Days to maturity (mean)	105	106	110
5.	Plant height, cm (mean)	143.3	152.6-160.7	169.1-178.2
6.	Test weight, g/10 ml (mean)	8.06	8.03	8.02
7.	Grain colour	Light creamy white	Creamy white	Creamy white
8.	Average grain yield, kg/ha	1821	1642	1591

Grain quality and biochemical composition

The biochemical composition of SKNA 401 and the check varieties is presented in Table 4. SKNA 401 recorded a protein content of 11.52%, which was marginally higher than that of GA 3 (11.42%) and GA 2 (11.29%). The genotype also exhibited a higher lysine content (8.58 g/100 g protein) than GA 3 (7.69 g/100 g protein) and GA 2 (6.12 g/100 g protein), indicating its superior protein quality. The higher lysine content observed in SKNA 401 is consistent with previous reports highlighting grain amaranth as an excellent source of high-quality protein with a favourable

amino acid composition (Caselato-Sousa and Amaya-Farfan, 2012; Rivero-Meza *et al.*, 2023).

The oil content of SKNA 401 was 7.80%, while micronutrient analysis revealed iron, zinc, copper and manganese contents of 16.45, 2.90, 0.21 and 1.20 mg/100 g, respectively. Although the iron content was lower than that of GA 3, SKNA 401 recorded zinc content comparable to the check varieties. The improved protein quality together with its favourable micronutrient composition indicates the nutritional potential of SKNA 401 as a grain amaranth variety for food and nutritional security.

Table 4 : Grain biochemical composition of SKNA 401 (GA 6) and check varieties

Sr. No	Parameter	SKNA 401	GA 3	GA 2
1.	Protein content (%)	11.52	11.42	11.29
2.	Lysine (g/100 g protein)	8.58	7.69	6.12
3.	Oil content (%)	7.80	—	8.50
4.	Fe (mg/100 g)	16.45	27.0	19.40
5.	Zn (mg/100 g)	2.90	2.80	2.95
6.	Cu (mg/100 g)	0.21	0.29	0.29
7.	Mn (mg/100 g)	1.20	1.40	1.35

Reaction to diseases and insect pests

No economically important incidence of major diseases or insect pests, including storage pests, was observed in SKNA 401 under natural field conditions throughout the evaluation period. The genotype exhibited satisfactory field tolerance

to the prevailing biotic stresses and performed comparably to the check varieties under the experimental conditions.

Implications for varietal development

The results of the present study demonstrated that SKNA 401 possesses several desirable attributes, including

superior grain yield, early maturity, favourable agronomic characteristics and enhanced grain quality. The consistent performance of the genotype across multi-location evaluations under Gujarat conditions indicates its suitability for cultivation in the target production environments. Collectively, these findings highlight the potential of SKNA 401 as a valuable genetic resource for grain amaranth improvement and varietal development programmes.

The variety Gujarat amaranth 6 is released by Central Variety Release Committee and Notified under the Gazette of India with notification No. S.O. 456(E) Sr. No. 131, New Delhi, dated 29, January, 2021.

The variety Gujarat amaranth 6 is deposited at NBPGR, New Delhi for long term storage and allotted IC Number (IC 631711) by ICAR-NBPGR.

CONCLUSION

SKNA 401, a grain amaranth genotype developed through pure-line selection at the Centre for Crop Improvement, Sardarkrushinagar Dantiwada Agricultural University, was evaluated over a ten-year period under state and national coordinated trials. The genotype consistently outperformed the check varieties in grain yield under Gujarat conditions and exhibited desirable agronomic characteristics, including early maturity, reduced plant height and superior grain quality, particularly with respect to protein and lysine content. Molecular characterization confirmed its genetic distinctness from the existing check varieties, while field

evaluation demonstrated satisfactory tolerance to the major diseases and insect pests encountered during the study period. The combined agronomic performance and grain quality of SKNA 401 demonstrate its suitability for cultivation under the agro-climatic conditions of Gujarat and its potential as a valuable genetic resource for future grain amaranth improvement programmes.

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