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SPV 3104: A STAY GREEN *rabi* SORGHUM CULTURE WITH HIGH TEST WEIGHT AND MODERATE RESISTANCE TO CHARCOAL ROT

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ABSTRACT

SPV 3104 is a pure-line selection derived from the local landrace TSLC 11. Multilocation evaluation under the All India Coordinated Research Project (AICRP) on Sorghum during 2023–2026, across 17–19 locations representing major *rabi* sorghum-growing regions of India, demonstrated its superior and stable performance over the national check varieties M 35-1, CSV 29R, and CSV 22R. The genotype was identified as a promising donor for test weight, charcoal rot resistance, and stay-green ability, making it a valuable resource in *rabi* sorghum improvement programmes. DUS characterization revealed 9–12 distinguishing morphological traits between SPV 3104 and each reference variety, thereby establishing its distinctness. In addition, DNA fingerprinting using 34 Simple Sequence Repeat (SSR) markers identified six polymorphic markers that differentiated SPV 3104 from the widely cultivated elite *rabi* sorghum varieties. These molecular markers provided additional evidence of its genetic distinctness and varietal identity. The combined evidence from multilocation evaluation, DUS characterization, and molecular fingerprinting establishes SPV 3104 as a distinct, stable, and agronomically valuable genetic resource for strengthening *rabi* sorghum breeding programmes, particularly for improving grain quality, charcoal rot resistance, and stay-green traits

Key words: charcoal rot, *rabi*, stay green score, test weight

Introduction

Sorghum (*Sorghum bicolor* (L.) Moench) is one of the world's important cereal crops, cultivated for food, feed, fodder, and fuel. Owing to its adaptability to drought, high temperatures, and marginal environments, it plays a crucial role in ensuring food and nutritional security. Globally, the crop is cultivated over an area of 40.7 million hectares, with an annual production of 62.4 million tonnes and an average productivity of 1,530 kg ha⁻¹ (USDA-FAS, 2025).

India ranks first in terms of area and fourth in terms of production worldwide. It is the second important dryland cereal crop after pearl millet and occupies 4.74 million hectares, producing 3.8 million tonnes with an average productivity of 1,250 kg ha⁻¹ (DA & FW, 2026). Sorghum is cultivated in both the rainy (*kharif*) and post-

rainy (*rabi*) seasons. Approximately 80 % of the cultivated area is under *rabi* which is primarily grown for human consumption because of its superior grain quality, while the remaining 20 % is cultivated during *kharif* season mainly for animal feed, fodder, and industrial uses.

In India, *rabi* sorghum is predominantly cultivated under rainfed conditions on conserved residual soil moisture in the states of Maharashtra, Karnataka, Telangana, and Andhra Pradesh. The crop is highly valued for its bold, lustrous grains with excellent culinary quality and its nutritious dry fodder, making it an integral component of mixed crop-livestock production system in the country.

The identification of stable donors for test weight is an important strategy in sorghum improvement programmes, as bold grains command a premium market

price and contribute positively to grain yield. Test weight is a key grain quality trait that influences market acceptance and overall economic returns to farmers. Landraces, which have been cultivated by farmers over several generations represent valuable reservoirs of genetic variation. These traditional cultivars have been reported as stable sources of grain quality traits, adaptation, and tolerance to biotic and abiotic stresses (Elangovan *et al.*, 2012). Therefore, efforts were directed towards identifying stable sources for high test weight from locally adapted sorghum landraces to facilitate their utilization in breeding programmes aimed at improving grain quality and productivity.

Charcoal rot, caused by *Macrophomina phaseolina* (Tassi) Goid., is one of the most destructive diseases of sorghum, particularly in the semi-arid tropics, where crop is frequently exposed to terminal drought and high temperatures during the grain-filling stage. The disease primarily infects the roots and basal stem tissues, leading to pith disintegration, stalk shredding, lodging, premature senescence, and significant reductions in both grain and fodder yield. In India, charcoal rot is especially severe in post-rainy sorghum, where residual soil moisture followed by prolonged moisture stress provides highly favourable conditions for disease development. The pathogen survives in the soil and infected crop residues as microsclerotia for several years and possesses a wide host range, making its management through cultural practices only partially effective (Gupta *et al.*, 2012). Hence cultivation of resistant cultivars is indispensable for the effective management of charcoal rot.

The stay-green trait is a key selection criterion in the development of *rabi* sorghum cultivars because of its strong association with adaptation to terminal drought. Visual stay-green scoring at physiological maturity is routinely employed to identify drought-tolerant genotypes in sorghum breeding programmes. The stay-green trait represents an important physiological mechanism of post-anthesis drought adaptation in sorghum, characterized by delayed leaf senescence and prolonged maintenance of photosynthetically active leaf area during grain filling under terminal moisture stress (Borrell *et al.*, 2000a; Tao *et al.*, 2000). Maintenance of green leaf area enables continued assimilate production during grain filling and has been associated with increased post-anthesis biomass production, improved grain filling and higher grain yield under drought conditions (Borrell *et al.*, 2000b). The trait is also associated with improved lodging resistance under terminal drought, as delayed senescence helps maintain plant structural integrity during grain filling (Borrell *et al.*, 2000c). Stay-green has additionally been reported to

be associated with reduced charcoal-rot severity; however, nonsenescence and charcoal-rot resistance are not necessarily controlled by the same genetic mechanisms (Tenkouano *et al.*, 1993). Therefore, stay-green is considered an important component of drought adaptation in *rabi* sorghum and can contribute to improved grain yield stability and reduced lodging under post-flowering moisture stress.

DUS (Distinctness, Uniformity, and Stability) traits are highly valuable in plant breeding, germplasm management, and genetic research, with applications extending well beyond plant variety protection (Singh and Singh, 2022). DUS descriptors provide a standardized morphological characterization facilitating accurate identification and comparison. It enables the identification of breeding materials possessing unique and desirable morphological characteristics that can be utilized as parents in hybridization programmes. Furthermore, standardized DUS descriptors serve as reliable passport data for the documentation, maintenance, and management of germplasm collections in gene banks and breeding programmes. Comprehensive DUS records establish the identity and genetic integrity, provide evidence of varietal originality, distinctness, and support for plant variety registration and protection under the Protection of Plant Varieties and Farmers' Rights Act (PPV&FRA, 2019).

DNA fingerprinting is a molecular technique used to identify and distinguish plant varieties based on polymorphisms in their DNA sequences. Unlike morphological descriptors, DNA markers are largely unaffected by environmental conditions, management practices, or the developmental stage making them highly reliable tools for varietal identification (Patil *et al.*, 2016). DNA fingerprinting provides precise genetic evidence of varietal identity, genetic purity, and distinctness in sorghum (Upadhyaya *et al.*, 2013; Adugna *et al.*, 2014). Furthermore, it generates reproducible and transferable molecular profiles that support variety registration, germplasm characterization, exchange and protection of intellectual property rights.

Materials and Methods

The sorghum culture SPV 3104 (Fig. 1) is a pure-

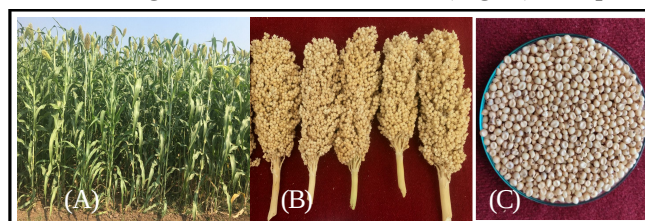


Fig. 1: (A) Field view, (B) Panicles and (C) Grain of SPV 3104.

SY: % Superiority

Table 5: Mean Performance of SPV 3104 at various locations with respect to Charcoal rot reaction during *Rabi* 2023-26

S. No.	Year, Location	23-24			24-25		25-26				Mean	Disease reaction
	Entry	Solapur	Bijapur	Hagari	Solapur	Hagari	Parbani	Solapur	Hagari	Bijapur		
1	SPV3104	18	31	25	25.7	26.8	17.7	23.5	23.9	14.6	22.9	MR
2	CSV 22 (C)	23	29	26	27.5	29.0	16.4	19.8	31.1	19.4	24.6	MR
3	CSV 29R (C)	17	17	18	26.5	29.6	17.1	20.0	26.2	9.6	20.1	MR
4	M35-1 (C)	17	24	36	27.4	32.2	17.9	15.8	30.4	14.1	23.9	MR
5	E36-1 (C)	21	27	32	16.5	16.1	13.2	13.7	14.3	10.2	18.3	MR
	Mean	20.7	26.4	30.3	24.7	26.7	18.2	22.4	27.1	15.1	23.5	
	C.D. (5%)	5.2	10.6	11.5	10.5	9.3	4.2	8.5	10.4	7.5	8.6	
	C.V. (%)	15	25	23	21.3	19.1	14.2	23.0	23.4	29.9	21.5	
MR: Moderately resistant												

weight than the checks at 16 of the 18 test locations (Table 1). The culture recorded an All India mean test weight of 3.64 g (rank 1), compared with CSV 22R (3.15 g; rank 27), CSV 29R (3.21 g; rank 22), and M 35-1 (3.32 g; rank 24).

In the Advanced Varietal/Hybrid Trial-I (Deep Soil) during *Rabi* 2024–25, SPV 3104 was again ranked first for test weight among 32 genotypes, including the checks. It recorded higher test weight than the checks at 12 of the 17 test locations (Table 2). The culture recorded an All India mean test weight of 3.69 g (rank 1), compared with CSV 22R (3.37 g; rank 11), CSV 29R (3.34 g; rank 14), and M 35-1 (3.22 g; rank 19). In the Advanced Varietal/Hybrid Trial-II (Deep Soil) conducted during *Rabi* 2025–26, the culture ranked sixth for test weight among 25 genotypes, including the checks. It recorded higher test weight than the checks at 8 of the 19 test locations (Table 3). The All India mean test weight was 3.57 g, compared with CSV 22R (3.44 g; rank 13), CSV 29R (3.43 g; rank 14), and M 35-1 (3.36 g; rank 19).

Based on Mean data from three years of multilocation evaluation, SPV 3104 exhibited 9.3%, 9.1%, and 11.4% higher test weight than CSV 22R, CSV 29R, and M 35-1, respectively (Table 4). Previous studies have demonstrated substantial genetic variability for test weight in sorghum germplasm and identified promising sources with high 100-seed weight in indigenous collections and

the sorghum mini-core collection (Elangovan *et al.*, 2020; Upadhyaya *et al.*, 2019). Test weight is an important yield component and grain quality trait in *rabi* sorghum, influencing grain size, milling recovery, and market acceptability. Therefore, the identification of bold-seeded germplasm such as SPV 3104 is valuable for sorghum improvement programmes, as it provides a useful donor for enhancing grain quality and consumer preference while contributing to the development of high-yielding cultivars with superior market value.

Charcoal rot reaction

The culture recorded a mean charcoal rot index (CRI) of 22.9 when compared to checks CSV 22R (24.6), CSV 29R (20.1) and M 35-1 (23.9) when tested at 4 locations over 3 years. The resistant check E 36-1 recorded a CRI value of 18.3 (Table 5). This indicates that the culture is moderately resistant to charcoal rot similar to the elite checks. Charcoal rot disease is a great concern in *Rabi* season in tropical and subtropical regions as most of the crop is grown on residual soil moisture after cessation of rainfall. The indirect loss computed due to charcoal rot alone amounts to 23-64 % (Das *et al.*, 2018). Development and cultivation of resistant cultivars is the most feasible and sustainable option for the management of the disease (Sharma *et al.*, 2022). Accurate phenotyping is a major challenge in charcoal rot resistance breeding as disease incidence and severity

Table 6: Mean Performance of SPV 3104 at various locations with respect to Stay green score during *Rabi* 2023-26.

S. No.	Year, Location	23-24		24-25			25-26			Mean
	Entry	Parbani	Dharwad	Solapur	Parbani	Dharwad	Parbani	Dharwad	Bijapur	
1	SPV3104	3.3	4.7	3.7	2	5	4.0	2.7	4.0	3.7
2	CSV22R©	3.0	3	2.7	2	4.7	3.3	3.0	3.3	3.1
3	CSV29R©	2.0	1.7	2.7	2.3	4.7	3.7	3.0	2.0	2.8
4	M35-1©	3.3	3.7	2.3	2.3	5	4.0	3.3	3.3	3.4
5	E36-1©	4.0	5.0	2.0	3.3	4.7	4.7	2.3	1.7	3.5
	Mean	2.6	3.2	2.7	2.7	4.9	3.9	2.7	2.7	3.2
	C.D. (5%)	0.9	1.2	1.2	0.9	0.7	1.3	0.9	1.29	1.0
	C.V. (%)	20.5	22.3	28.5	19.5	8.1	21.1	20.1	29	21.1

Table 7: DUS characterisation of SPV 3104 along with reference varieties.

Sr.	Characteristics	SPV 3104	M35-1	CSV 22R	CSV 29R
1	Seedling Anthocyanin colouration of coleoptile	Greyed purple			
2	Leaf sheath: Anthocyanin pigmentation	Greyed purple			
3	Leaf: Midrib colour (5 th fully developed leaf from bottom)	Yellow green			
4	Plant: Time to 50% flowering (50% of the plants with 50% anthesis)	Late (82days)	Medium	Medium	Late (76 days)
5	Plant:natural height of plant up to base of flag leaf	Medium	Medium	Tall	Medium
6	Flag leaf: Yellow Colouration of midrib	Present	Absent	Absent	Absent
7	Lemma: Arista formation	Present			
8	Stigma: Anthocyanin colouration	Present			
9	Stigma: Yellow colouration	Present	Absent	Present	Present
10	Stigma: Length (mm)	Long	Medium	Medium	Long
11	Flower with pedicel: Length of flower	Medium	long	Medium	long
12	Anther: Length (mm)	Medium	Medium	short	Medium
13	Anther: Colour of dry anther	Greyed orange	Greyed orange	Greyed orange	Yellow orange
14	Glume :Colour	Greyed orange	Greyed purple	Greyed orange	Greyed yellow
15	Plant: Total height (cm) at maturity (including panicle)	Medium	Medium	Tall	Medium
16	Stem : Diameter (at lower one-third height of plant) (cm)	Small			
17	Leaf: Length of blade (the third leaf from top including flag leaf) (cm)	Long	Medium	Long	Long
18	Leaf: Width of blade (the third leaf from top including flag leaf) (cm)	Broad			
19	Panicle : Length without peduncle (cm)	Medium	Short	Medium	Medium
20	Panicle : Length of branches (middle third of panicle) (cm)	Medium			
21	Panicle : Density at maturity (ear head compactness)	Semi loose	Semi compact	Semi loose	Semi compact
22	Panicle : Shape	Symmetric	Broader in lower part	Symmetric	Broader in lower part
23	Neck of panicle : Visible length above sheath (cm)	Very short	Short	Very long	Very short
24	Glume : Length	Short	Medium	Medium	Medium
25	Grain: Threshability	Freely threshable			
26	Grain: Colour after threshing	Yellow white	Yellow white	Greyed orange	Yellow orange
27	Grain : Weight of 1000 grains (g)	High	Medium	Medium	Medium
28	Grain: Shape (in dorsal view)	Circular			
29	Grain: Size of mark of germ	Large	Large	Medium	Large
30	Grain: Texture of endosperm (in longitudinal section)	3/4farinaceous			
31	Grain: Colour of vitreous albumen	Greyed yellow			
32	Grain :Lustre	Lustrous			

vary considerably across locations and years. To overcome this limitation, Das *et al.*, (2018) developed a charcoal rot rating index that integrates disease incidence and severity, thereby providing a more stable assessment of genotype performance across multilocation trials. This standardized index has greatly improved the identification of resistant germplasm and facilitates more reliable comparison of breeding materials under diverse environmental conditions.

Stay green score

The entry SPV 3104 (3.7) recorded higher mean

stay green score values over the checks CSV 22R (3.1), CSV 29R (2.8), M35-1 (3.4) and stay green check E 36-1 (3.5) when evaluated during *Rabi* 23-26 at 4 locations (Table 6). Several sources of stay-green have been identified in sorghum and utilized in breeding programmes for improving adaptation to terminal drought. B35, derived from the Ethiopian germplasm accession IS 12555, is widely used donor of stay-green, with several major QTLs, including Stg1, Stg2, Stg3 and Stg4, identified from B35-derived populations (Xu *et al.*, 2000; Tao *et al.*, 2000). Other genetically diverse sources, include E36-1, SC56, KS19, QL41, IS 22380, QL27 and QL10, for

Table 8: List of SSR markers used for amplification.

S. No	Marker	Forward sequence	Reverse sequence
1	Xtxp6	ATCGCATCCGTCAGATC	TCTAGGGAGGTTGTCAT
2	Xtxp63	CCAACCGCGTCGCTGATG	TCTAGGGAGGTTGCCAT
3	Xtxp235	AAATCATGCATCCATGTTTCGTCTT	CTCCCGCTACAAGAGTACATTCATAGC
4	Xtxp88	CGTGAATCAGCGAGTGTTGG	TGCGTAATGTTCTCTGCTC
5	Xtxp8	ATATGGAAGGAAGCCGG	AACACATGCACGCATG
6	Xtxp21	GAGCTGCCATAGATTTGGTCG	ACCTCGTCCCACCTTTGTTG
7	Xtxp326	TATTTCTCTTGAAGAATCAGGG	TATTCATCGAGCAAAAGGGCA
8	Xtxp230	CGTACCGCTGCTGCTCT	AGGGGGCATCCAAGAAAT
9	Xtxp9	AATAGCACCGCCGCGCG	CATTGTGGAGTCCCTGATAC
10	Xtxp12	AGATCTGGCGGCAACG	AGATCTGGCGGCAACG
11	Xtxp31	GCGAGGCTGCCCTACTAG	GCGAGGCTGCCCTACTAG
12	Xtxp15	CACAAACACTAGTGCCTTATC	CATAGACACCTAGGCCATC
13	Xtxp321	TAACCCAAGCCTGAGCATAAGA	CCCATTACACATGAGACGAG
14	Xtxp141	TGTATGGCCTAGCTTATTCT	CAACAAGCCAACCTAAA
15	Xtxp340	AGAAGTGTGCATGTATTCGTC	AGAATCATCCAAACTCCAATT
16	Xtxp33	GAGCTACAGAGGGTTCAAC	CCTAGCTATTCCTTGTTG
17	Xtxp61	GATGCCCATGCCTTGC	CCCACTAAACTAAAGCGGACA
18	Xcup 69	ACAGACCAAGGTGAAGGAC	ATGTAGGGCACCAGCTTCAC
19	Xgap 10	GTGCCGCTTTGCTCGCA	TGCTATGTTGTTTGCTTCTCCCTTCTC
20	mSbCIR246	TTTTGTTGCACTTTTGAGC	GATGATAGCGACCACAAATC
21	Xtxp 320	TAAACTAGACCATATACTGCCATTAA	GTGCAAATAAGGGCTAGAGTGTT
22	Xcup 53	GCAGGAGTATAGGCAGAGGC	CGACATGACAAGCTCAAACG
23	Xcup 11	TACCGCCATGTCATCATCAG	CGTATCGCAAGCTGTGTTTG
24	Xtxp 136	GCGAATAGCATCTTACAACA	ACTGATCATTGGCAGGAC
25	Xtxp 10	ATACTATCAAGAGGGGAGC	AGTACTAGCCACACGTCAC
26	Xtxp 354	TGGGCAGGGTATCTAACTGA	GCCTTTTTCTGAGCCTTGA
27	mSbCIR240	GTTCTTGGCCCTACTGAAT	GTTCTTGGCCCTACTGAAT
28	Xtxp104	TAACCTATGCGGATAAAACAG	TAACCTATGCGGATAAAACAG
29	Xtxp40	CAGCAACTTGCCTTGTCT	GGGAGGAATTTGGCACTAG
30	Xtxp270	AGCAAGAAGAAGGCAAGAAGAAGG	GCGAAATTATTTTGAAATGGAGTTG
31	Xtxp312	CAGGAAAATACGATCCGTGCCAAGT	GTGAACTATTTCGGAAGAAGTTTGGAGGAAA
32	Xtxp69	ACACGCATGGTTTGACTG	TTGATAATCTGACGCAACTG
33	mSbCIR306	ATACTCTCGTACTCGGCTCA	GCCACTCTTACTTTTCTTCTG
34	Xtxp278	GGGTTTCAACTCTAGCCTACCGAACTTCT	ATGCCTCATCATGGTTCGTTTGTCTT

delayed leaf senescence and post-flowering drought tolerance (Mahalakshmi and Bidinger, 2002). B35 has been extensively used to identify and validate stay-green QTLs in crosses with the widely adapted cultivar M 35-1 (Rama Reddy *et al.*, 2014). More recently, stay-green donors such as K260 and K359w carrying Stg3A and Stg3B QTLs, respectively, were introgressed into farmer-preferred *rabi* sorghum cultivars (Diwakar Reddy *et al.*, 2025). These studies demonstrate the considerable value of stay-green germplasm for developing sorghum cultivars with improved tolerance to terminal moisture stress and greater yield stability under *rabi* situations.

DUS characterization

SPV 3104 was characterized for 32 DUS descriptors to assess its distinctness in comparison with three widely

cultivated *rabi* sorghum reference varieties, M 35-1, CSV 22R and CSV 29R, which are routinely used as checks in AICRP trials. Of the 32 DUS descriptors evaluated, variation was observed for 20 traits, whereas the remaining 12 traits were uniform across all four genotypes (Table 7). The observed differences in qualitative and quantitative descriptors enabled clear discrimination of SPV 3104 from each of the reference varieties.

SPV 3104 was distinguished from M 35-1 by 12 descriptors, viz., time to 50% flowering, yellow coloration of stigma, stigma length, flower pedicel length, glume colour, leaf blade length, panicle length, panicle density, panicle shape, panicle neck, glume length and test weight. In comparison with CSV 22R, SPV 3104 differed for 11 descriptors, including time to 50% flowering, plant height

Table 9: Allelic status of SPV 3104 and checks.

S. No.	Marker	Allele size	SPV 3104	CSV 29R	CSV 22R	M 35-1
1	X cup 53	200bp	1	1	1	0
		180bp	0	0	0	1
2	X txp 69	170bp	1	0	0	1
		160bp	0	1	1	0
3	X cup 69	280bp	1	0	0	1
		260bp	0	1	1	0
4	X txp 230	200bp	1	1	1	0
		180bp	0	0	0	1
5	X txp 235	200bp	1	1	1	0
		180bp	0	0	0	1
6	X gap 10	320bp	0	1	1	0
		280bp	0	0	0	1
		260bp	1	0	0	0

up to the base of the flag leaf, yellow coloration of the flag-leaf midrib, stigma length, anther length, plant height at maturity including panicle, panicle neck, glume length, grain colour after threshing, test weight and germ mark of grain. Against CSV 29R, SPV 3104 exhibited differences for nine descriptors, namely yellow coloration of the flag-leaf midrib, flower pedicel length, colour of dry anther, glume colour, panicle density, panicle shape, glume length, grain colour after threshing and test weight.

The differential expression of these DUS descriptors, particularly those related to flowering time, panicle architecture, glume and grain characteristics, and test weight, provides clear morphological evidence supporting the distinctness of SPV 3104 from the reference varieties. The results demonstrate the usefulness of standardized DUS descriptors for establishing varietal identity and morphological distinctness in *rabi* sorghum. In sorghum breeding, DUS characterization has become relevant because many elite breeding lines share a narrow genetic base and exhibit similar agronomic performance. Under such circumstances, detailed morphological descriptors provide an effective means of distinguishing closely related genotypes. When combined with molecular marker analysis, DUS traits offer a comprehensive framework for variety identification, protection, maintenance breeding, and germplasm management.

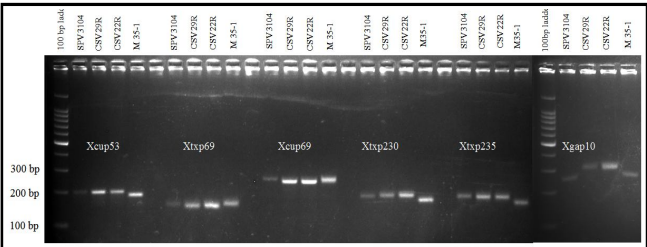


Fig. 2: PCR amplification of SPV 3104 along with checks with SSR markers.

DUS evaluation has become an integral component of sorghum breeding supporting the development, documentation, and conservation (Hariprasanna, 2019). Previous studies have established the identity of candidate varieties in comparison with reference varieties using DUS descriptors, thereby facilitating the registration and protection (Hariprasanna and Aruna, 2014, Hariprasanna *et al.*, 2015).

DNA Fingerprinting

SPV 3104 and the three reference varieties were subjected to molecular characterization using 34 SSR markers (Table 8). Of the 34 markers analyzed, six exhibited polymorphism among the genotypes, producing differential amplicon sizes and thereby enabling molecular discrimination of the entries (Fig. 2). Four SSR markers, namely Xcup53, Xtxp230, Xtxp235 and Xgap10, differentiated SPV 3104 from M 35-1, whereas Xtxp69, Xcup69 and Xgap10 distinguished SPV 3104 from CSV 22R and CSV 29R (Table 9). Notably, Xgap10 was informative for differentiating SPV 3104 from all three reference varieties, indicating its potential utility as a diagnostic marker for varietal identification.

The effectiveness of SSR markers in establishing genotype-specific molecular fingerprints and assessing genetic relationships in sorghum has been demonstrated in several earlier studies (Madhusudhana *et al.*, 2025, Ganapathy *et al.*, 2012, Mofokeng *et al.*, 2014, Santhiya *et al.*, 2020). The present findings further demonstrate the utility of SSR markers in complementing morphological DUS characterization by providing molecular evidence for the distinct identity of SPV 3104. The polymorphic markers identified in the present study can therefore serve as useful molecular fingerprints for the identification and genetic purity assessment of SPV 3104.

Conclusion

The development of improved *rabi* sorghum cultivars requires the identification of stable genotypes possessing superior grain quality, adaptation to terminal drought, and resistance to major diseases such as charcoal rot. Multi-location evaluation under diverse agroclimatic conditions is an essential component of varietal development, as it enables the assessment of genotype performance, stability, and adaptability across environments. In addition to agronomic evaluation, characterization using DUS descriptors provides standardized morphological evidence for varietal identification, while DNA fingerprinting complements DUS testing by establishing genetic identity and confirming varietal distinctness. The integration of multi-location performance, DUS characterization, and molecular profiling provides a robust basis for identifying

elite breeding material such as SPV 3104 identified in the present study, facilitating its utilization in crop improvement.

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Competing Interests: The author(s) declare(s) that they have no competing interests.

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