Journal of Cereal Research
Volume 15 (2): 294-303
Homepage: http://epubs.icar.org.in/ejournal/index.php/JWR
Varietal Release

MACS 6768: A new high-yielding, disease-resistant, high-protein grain, and micronutrient-rich wheat variety

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Article history:
Received: 23 Mar., 2023
Revised: 22 Jul., 2023
Accepted: 28 Aug., 2023

Citation:
Yashavanthakumar KJ, S Navathe, VS Baviskar. MACS 6768: A new high-yielding, disease-resistant, high-protein grain, and micronutrient-rich wheat variety. *Journal of Cereal Research* ***15 (2):*** *294-303.* http://doi.org/10.25174/2582-2675/2023/135631

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Abstract

A high-yielding bread wheat cultivar MACS 6768 (MACS SAKAS) has been developed and launched by Agharkar Research Institute (ARI), Pune, India. It was released by CVRC after multilocation testing under high fertility irrigated circumstances of the central zone (CZ) of India. The new variety has a maximum yield potential of 92.4 q/ha with a mean yield of 56.6 q/ha. Central Sub-committee on Crop Standards, Notification and Release of Variety, Ministry of Agriculture, Government of India, issued notification number S.O. 1056(E) 2023 for cultivation in India's CZ. MACS 6768 (MACS SAKAS) promises to be one of a kind and excellent in yield, chapati-making score, protein, and nutrition (Fe & Zn). Its protein (12.0%), zinc (45.1 ppm), iron (41.2 ppm), and Chapati score are excellent. (8.3). It is a nutritious candidate for "Iron and Zinc bio fortified high yielding bread wheat" for chapati. Our new cultivar will offer nutritional security and better market price, making wheat agriculture more viable and promoting the Kuposhan Mukta Bharat objective.

Keywords: Bread wheat, Yield, Quality, Rust Resistance, Biofortification.

1. Introduction:

Wheat, the most important cereal, is the most significant source of calories relative to protein. Wheat provides approximately twenty per cent of the world's calorie and protein intake. Consequently, it is essential for worldwide food and nutritional security. Wheat accounts for approximately 30 per cent of the world's cereal production and is the most extensively cultivated crop on more than 200 million hectares. Wheat demand will increase by 60 percent by 2050 (Müller et al. 2018), despite the fact that global yields are stagnating due to an expanding population. In addition, wheat is especially vulnerable to climate change and emerging pathogens, such as the wheat blast. Genetic yield improvements persist in the world's staple crops (Li et al. 2018) but improved agronomic practices are necessary to realise the potential of these yield improvements in farmer's fields and meet global demand (Fischer and Connor 2018). Breeders endeavour continually to improve genotypes by modifying genetically complex yield and end-use quality parameters while maintaining stable yields and adapting the crop to regionally specific biotic and abiotic stresses.

India is the second most wheat producer on the globe. The All India Coordinated Wheat Improvement Project (AICWIP) was initiated in 1965 as one of the largest crop improvement network initiatives involving inter-disciplinary and inter-institutional collaboration (Khan et al., 2021). This marked the beginning of the 'Green Revolution' in India. The Central Zone (CZ) (Madhya Pradesh, Chhattisgarh, Gujarat, Kota and Udaipur divisions of Rajasthan, and Jhansi of Uttar Pradesh) is a

mega environment for wheat cultivation in the country, encompassing 7 million hectares and producing 21 million metric tonnes. Sustaining wheat production in this zone requires the introduction of varieties with higher and more stable yields, resistance to main diseases, and high adaptability to climate change. Currently, the development of nutrient-dense primary food crops is one of the most important research areas for scientists around the world, even though yield is the top priority during varietal development. Therefore, the development of high-yielding and nutrient-dense (high protein, iron, zinc, etc.) wheat varieties is prioritised in India. The rapid emergence of novel races of rust pathogens with virulence against the numerous widely deployed rust resistance genes in wheat has increased the emphasis on diversifying and pyramiding resistance genes (Gangwar et al., 2021). The rust maladies have been brought under control primarily through the development of resistant wheat varieties by wheat researchers in India (Khan et al., 2021).

Since 1954, the MACS-Agharkar Research Institute has engaged in crop research leading to improved varieties, making it one of the few pioneering institutions in the country. In the wheat breeding programmes of MACS-ARI, Pune, an adequate level of yield, quality, nutrition, adaptability, and genetic resistance to stem and leaf rust pathotypes is a primary breeding objective. MACS-ARI Pune developed and released several wheat cultivars, including MACS 6222, MACS 6478, MACS 3949, and MACS 2971, for timely sown irrigated conditions in the PZ over the past decade. In this regard, we sought to cultivate bread wheat varieties with greater adaptability in CZ and PZ zones and higher yields. A new high-yielding input-responsive wheat variety, MACS 6768 (MACS SAKAS), was recently developed and released for high fertility and irrigated conditions in the central zone. Preferred traits include medium maturity, stem and leaf rust resistance with nutritional quality characteristics, especially protein, iron, and zinc.

2. Materials and Methods

MACS 6768 (MACS SAKAS), a newly developed high-yielding bread wheat variety brought about by MACS-ARI, Pune, is the result of an in-house crossing and selection programme. It is descended from the parents MACS 6221*2 // Raj 4037. The pedigree method was used for selection and promotion of breeding lines within and between families at segregating generations until the F6 generation. Later, head to rows from family selection were planted to evaluate the best sister lines as well as across family lines. The most productive lines were chosen based on yield, yield contributing features and rust resistance. The chosen lines were initially evaluated at the station level for small plot replicated, big plot replicated, and big plot replicated multilocation testing. Later, they were subjected to countrywide coordinated trials as part of the ICAR-AICRP for the wheat programme, which was coordinated by IIWBR Karnal. Multilocation studies were undertaken over three years to assess yield stability, agronomic adoption, disease resistance, and quality components.

Rust severity and response at the adult plant stage were rated simultaneously across locations in the Plant Pathological Screening Nursery (PPSN) using the modified Cobbs scale described by Peterson et al. (1948). The average coefficient of infection (ACI) for both rusts, as described by Saari and Wilcoxson (1974) by multiplying disease severity by constant infection type values. The following constant values were utilised for infection types: R = 0.2, MR = 0.4, M = 0.6, MS = 0.8, and S = 1.0. At the Rust Laboratory Shimla, gene postulation for rust resistance genes was performed following seedling resistance tests (SRT) using the 0-4 scale of Stakeman (1962) against numerous pathotypes of three rusts *Puccinia striiformis tritici* (Pst), *P. triticina* (Ptr), and *P. graminis tritici* (Pgt). For the characterization of MACS 6768, the PPVFRA (2007) criteria for the conduct of tests for Distinctiveness, Uniformity, and Stability (DUS) on wheat (*Triticum aestivum* L.) were followed**.**

3. Results and Discussion

3.1 Yield evaluation in AICWIP trials:

The productivity of MACS 6768 was evaluated in NIVT & AVT for three years, during the course of which it demonstrated superior and stable yielding potential under timely sown irrigated conditions throughout Central Zone India. The average performance of the coordinated trials over the course of three years (2019-2020, 2020-2021, and 2021-22) in comparison to the controls, HI 1544, and GW 322 (Table 1). MACS 6768 has a maximum production potential of 92.4 q/ha (in NIVT) and an average yield of 56.6 q/ha. On a global scale, the new variety MACS 6768 demonstrated yield gains of 11, 6, 3.9, and 1.8% relative

to the control varieties HI 1636, GW 513, HI 1544, and GW 335, respectively, and 4.1% relative to the qualifying entry MP 3535. MACS 6768 was more likely to appear in the first non-significant group (15/38) than the checks GW322 (15/38) and HI 1544 (10/38).

Table 1: Performance MACS 6768 over checks for grain yield under coordinated cropping season 2019-2022

Items	Year of testing	Trials	Proposed variety	Check varieties				Qualifying Entries	
			MACS 6768	GW 322	HI 1544	GW 513	HI 1636	HI 1650	MP 3535
Yield (q/ha)	2019-20 (NIVT 2)	9	62.2	58.8	58.1	-	-	62.8	62.8
	2020-21 (AVT I)	14	54.8	53.4	52.8	53	50.3	55.3	56.6
	2021-22 (AVT II)	15	54.9	56.6	54.5	55.1	52.9	55.6	45.8
	Mean		**57.3**	**56.3**	**55.1**	**54.1**	**51.6**	**57.9**	**55.1**
	Weighted mean		**56.6**	**55.9**	**54.7**	**54.1**	**54.9**	**57.2**	**53.8**
% Increase/decrease over checks & qualifying varieties	2019-20 (NIVT 2)			5.8	7.1	-	-	-1.0	-1.0
	2020-21 (AVT I)			2.6	3.8	3.4	8.9	-0.9	-3.2
	2021-22 (AVT II)			-3.0	0.7	-0.4	3.8	-1.3	19.9
	Over mean			**1.8**	**3.9**	**6.0**	**11.0**	**-1.0**	**4.1**
Frequency in 1st NS group	2019-20 (NIVT 2)		4	2	2	-	-	6	6
	2020-21 (AVT I)		5	5	4	6	2	8	9
	2021-22 (AVT II)		6	8	4	3	4	6	0
	Total		**15/38**	**15/38**	**10/38**	**9/29**	**6/29**	**20/38**	**15/38**

3.2 Performance of MACS 6768 for agro-morphological traits:

The average height of this variety is 87 cm, and it is resistant to lodging. This variety typically reaches physiological maturity between 83 and 143 days after sowing. However, days to maturity vary according to climate conditions. After the crop reaches physiological maturity, it may be harvested. This variety matures on average in 116 days. Compared to control varieties GW 322 (-13.37%) and HI 1544 (-11.90%) and a qualifying entry HI 1650 (-9.98%), MACS 6768 (-7.85%) has exhibited less yield loss under late sowing conditions.

3.3 Disease Resistance:

MACS 6768 revealed seedling resistance (all-stage resistance) to all 21 pathotypes of stem rust and 23 pathotypes of leaf rust. The postulated gene SRT data indicates Sr31+2+ Lr26 + R+Yr9+. It has exhibited stem and leaf rust resistance under both natural and artificial screening conditions. Under artificial conditions, leaf rust severity ranged from 5.8 to 12.1, with an average of 8.1, whereas stem rust severity ranged from 3.0 to 11.3, with an average of 6.0. The SRT data for gene postulation reveals Sr31+2+ Lr26 + R+Yr9+. It has demonstrated resistance to Karnal bunt, Powdery mildew, Leaf blight, Flag smut, and Footrot. (Table 2).

3.4 Quality traits and marker analysis:

It has demonstrated superior nutritional quality with elevated levels of protein (12%), zinc (45,1 ppm), and iron (41.2 ppm). Amber-colored grain weighing 44 grammes per thousand grains and 82.1 kilogrammes per hectoliter. MACS 6768 has excellent chapati quality, as indicated by its high Chapati score of 8.3 (Table 3). Overall, it is a nutrient-dense candidate variety that has the potential to be used as "Iron and Zinc bio-fortified high yielding bread wheat" for chapati preparations. High molecular weight glutenin subunits (HMW-GSs) are storage proteins found

Table 2: Reaction to rust diseases in natural and artificial epiphytotic conditions.

Disease	Year	Proposed Variety		Check Varieties								Qualifying Entries			
		MACS 6768		GW 322		HI 1544		GW 513		HI 1636		HI 1650		MP 3535	
		HS	ACI	HS	ACI	HS	ACI	HS	ACI	HS	ACI	HS	ACI	HS	ACI
Brown Rust															
Natural condition	2019-20	0	0	tMR		0	0	0	0	0	0	0	0	tMR	
	2020-21	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2021-22	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Highest Score & Mean ACI	0	0	tMR		0	0					0	0	tMR	
Artificial condition	2019-20	40S	5.7	40S	11.1	40MS	4.1	0	0	0	0	20MR	1.1	20S	6.4
	2020-21	30S	6.4	20MS	7.3	40MS	5.8	20S	3.2	20MS	4.0	15MR	1.0	20S	4.9
	2021-22	60S*	12.1	30S	14.4	30S	6.1	20MS	3.3	5MR	0.4	20S	4.0	80S	24.8
	Highest Score & Mean ACI	60S*	8.1	40S	10.9	40MS	5.3	20S	3.3	20MS	2.2	20S	2.0	80S	12.0
Stem Rust															
Natural condition	2019-20	tR	tR	60S	60S	0	0	0	0	0	0	10R	10R	20S	20S
	2020-21	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2021-22	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Highest Score & Mean ACI	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Artificial condition	2019-20	40S	11.3	20S	12.8	10S	2.7	0	0	0	0	10MS	1.9	40S	13.5
	2020-21	20MS	3.8	30S	8.3	30S	5.3	10MS	3.3	10S	3.3	10S	2.8	20MS	3.1
	2021-22	20MR	3.0	20S	8.0	10MR	0.7	10MR	1.5	tMR	0.1	5MR	0.4	40S	28.7
	Highest Score & Mean ACI	40S	6.0	30S	9.7	30S	2.9	10MS	2.4	10S	1.7	10S	1.7	40S	15.1

HS = Highest score, ACI = Average coefficient of infection

Table 3: Performance of MACS 6768, along with checks for quality traits

Year	New Variety	Check Varieties				Qualifying Entries	
	MACS 6768	GW 322	HI 1544	GW 513	HI 1636	HI 1650	MP 3535
Nutritional quality							
Protein (%)	12.0	10.3	11.5	11.0	11.6	11.4	11.8
Fe (ppm)	41.2	36.6	40.4	38.2	36.3	39.5	39.9
Zn (ppm)	45.1	43.0	42.4	39.5	42.9	42.7	44.2
Phenol test (max score 10)	6.3	6.3	6.6	3.2	5.0	6.8	4.9
Grain Characteristics							
Grain appearance (max score 10)	6.8	6.5	6.9	7.1	7.0	6.9	6.7
Hectolitre weight (kg/hl)	82.1	79.8	82.0	82.7	81.3	82.6	82.5
Grain Hardness index	76.8	79.9	82.6	76.3	74.0	77.0	75.9
Chapati quality characteristics							
Sedimentation value (ml)	39.3	38.5	39.4	39.3	43.6	39.0	43.7
Wet gluten (%)	33.5	26.6	31.0	31.8	30.4	29.7	33.1
Dry gluten (%)	11.0	8.8	10.4	11.2	9.9	10.3	11.0
Gluten index (%)	40.0	62.0	51.0	50.0	50.0	59.0	36.0
Chapati (max score 10)	8.3	7.4	8.4	8.3	8.1	7.9	8.4
Bread Quality							
Bread loaf volume (ml)	430	445	424	413	383	452	458
Bread quality (max score 10)	4.0	4.6	4.0	4.0	3.3	4.3	4.4
Biscuit Quality							
Biscuit spread factor	7.7	8.5	7.8	7.8	7.8	7.5	7.6

in the wheat endosperm. The analysis of HMW subunits revealed Glu-D1(2+12), Glu-A1(2), and Glu-B1 (7+9), with a Glu-1 score of 7. These results indicate the variety's high chapati-making quality.

The marker profile was generated using a selected set of STS and ASPCR markers, revealing the presence of waxy gene (WxB1), abiotic stress DREB, Viviparous 1(Vp1B3), photoperiodism (Ppd- D1), vernalization (VrnA1A), and re-harvest Sprouting resistance (DuPW001).

3.5 Notification and seed production

MACS 6768 was recommended for commercial cultivation in the Central Zone (CZ) (Madhya Pradesh, Chhattisgarh, Gujarat, Kota and Udaipur divisions of Rajasthan, and Jhansi division of Uttar Pradesh) by the 'Central Sub-Committee on Crop Standard Notification and Release of Varieties for Agricultural Crops' of the Government of India via gazette notification number S.O. 1056(E) 2022). We have currently provided 3 quintals of breeder seed to the national seed certification organisation for MACS 6768 foundation seed production for the wheat season 2021-22. We sowed and obtained roughly 50 q of breeder seed for the 2022-23 sowing season at the institutional level. This cultivar, with multiple disease resistance and improved grain quality, is predicted to contribute significantly to India's food and nutritional security. MACS-ARI, Pune, has increased the scale of quality seed production of MACS 6768 to fulfil the high demand for this variety among farmers.

Acknowledgements: Authors are thankful to the Indian Council of Agricultural Research (ICAR), ICAR- Indian Institute of Wheat and Barley Research (ICAR-IIWBR) and Agharkar Research Institute for the funding and infrastructure facilities.

Declaration: Authors declare no conflict of interest.

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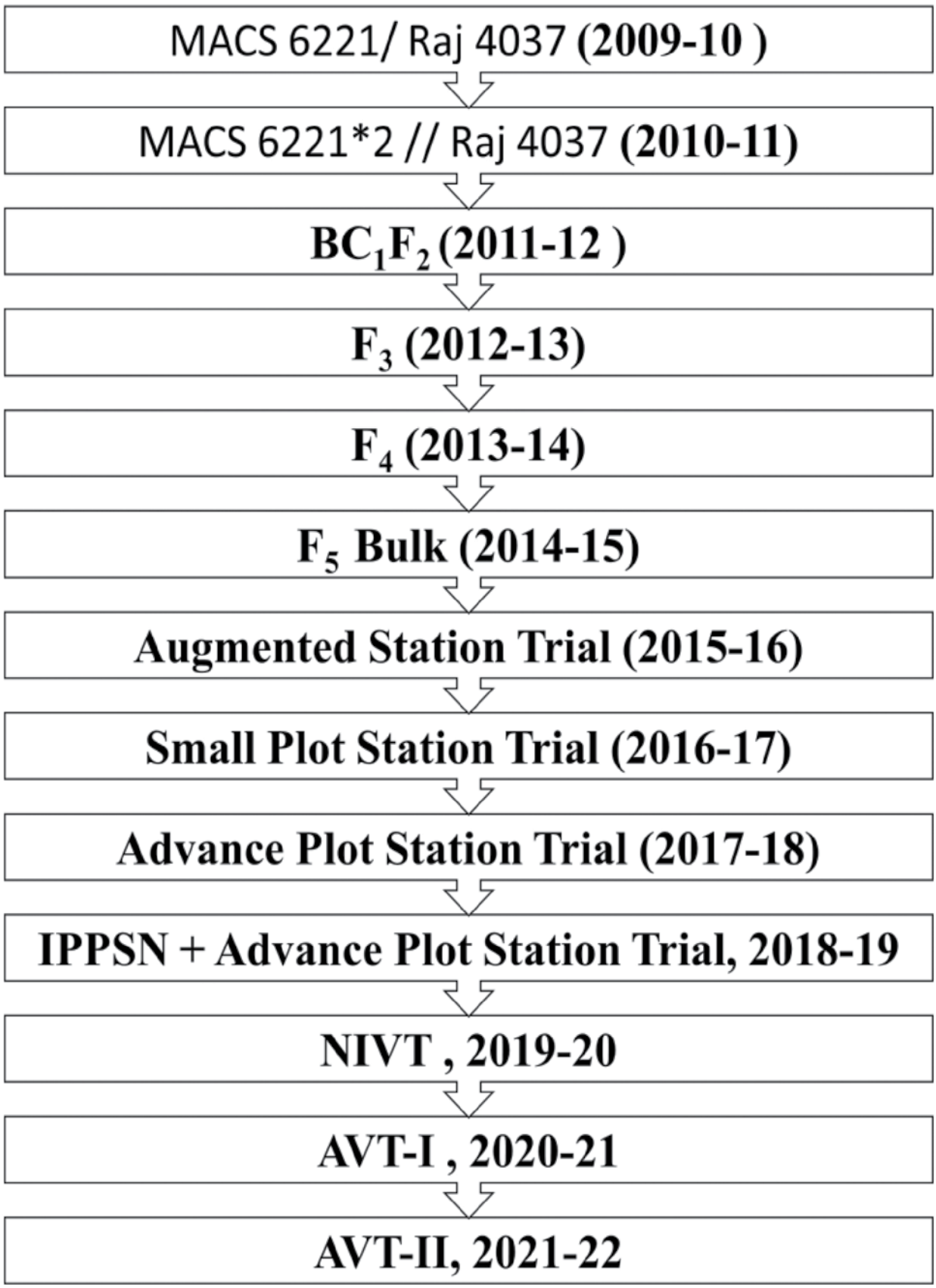

Fig. 1. Flow chart of details of the development of bread wheat variety MACS 6768

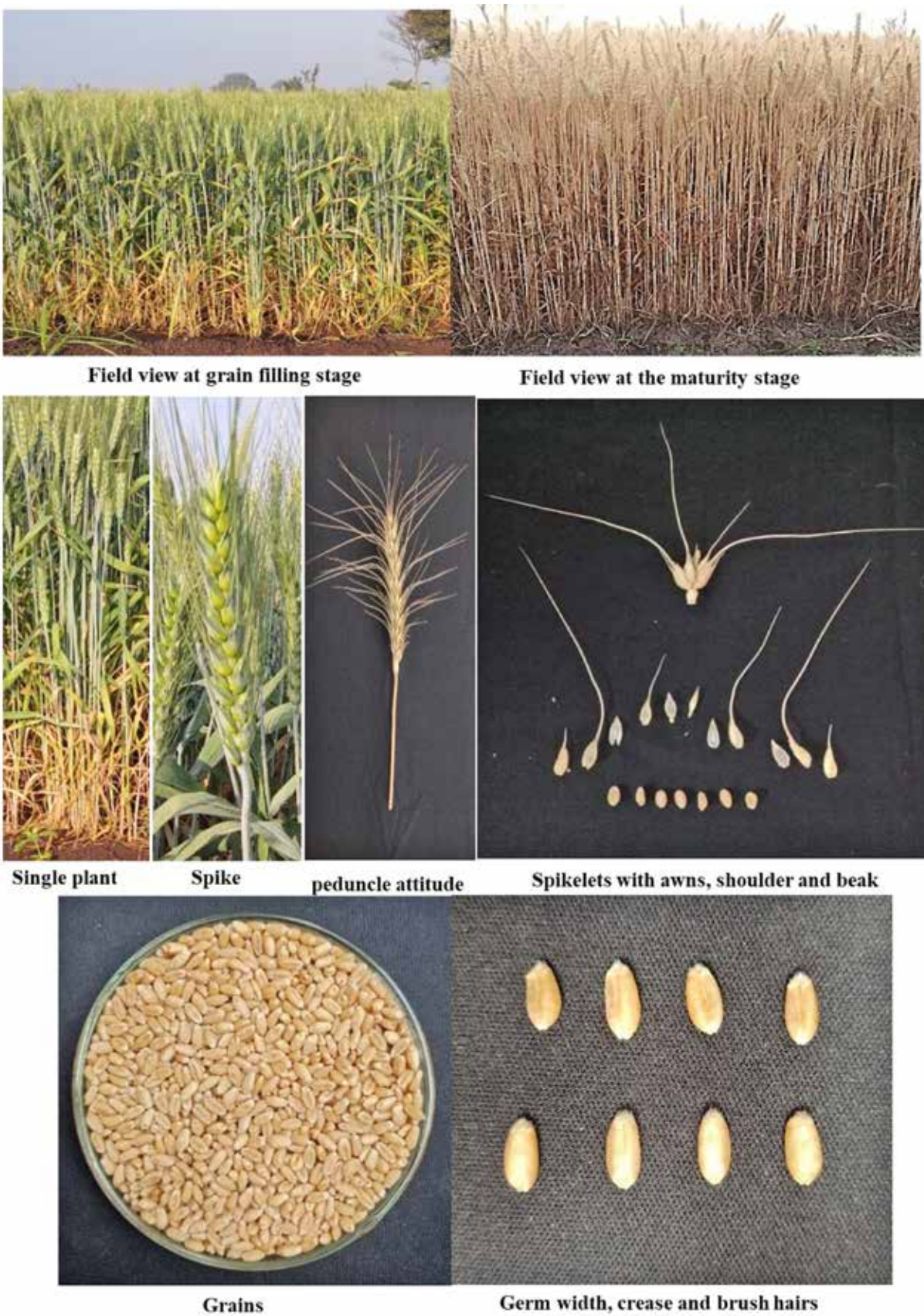

Fig. 2. The pictorial presentation of the various characters includes a single-plant view, spikelets with awns and grain characters

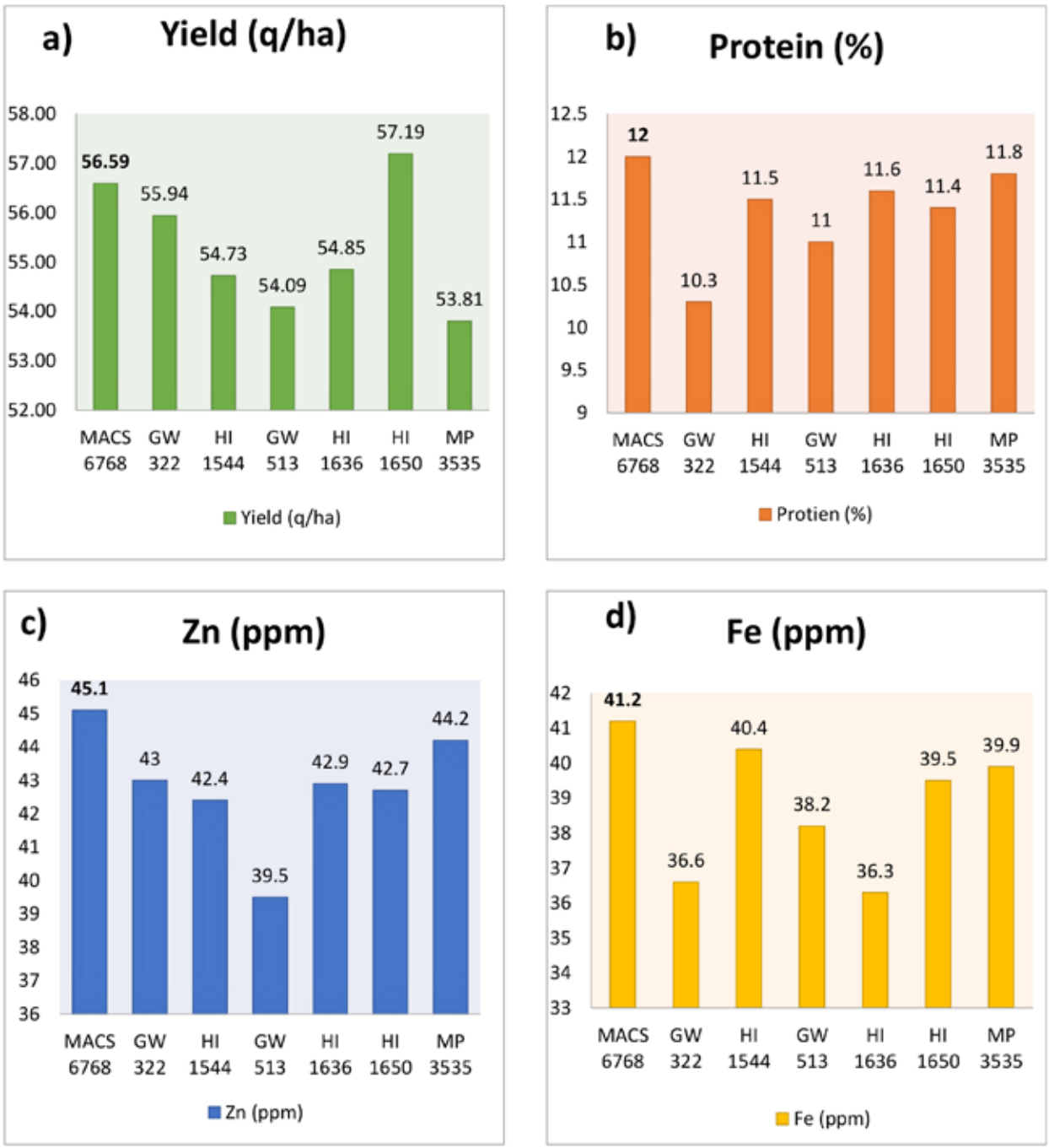

Fig. 3. Comparisons of the yield performance protein content, Zink and iron content of the MACS 6768 with leading wheat varieties in central India

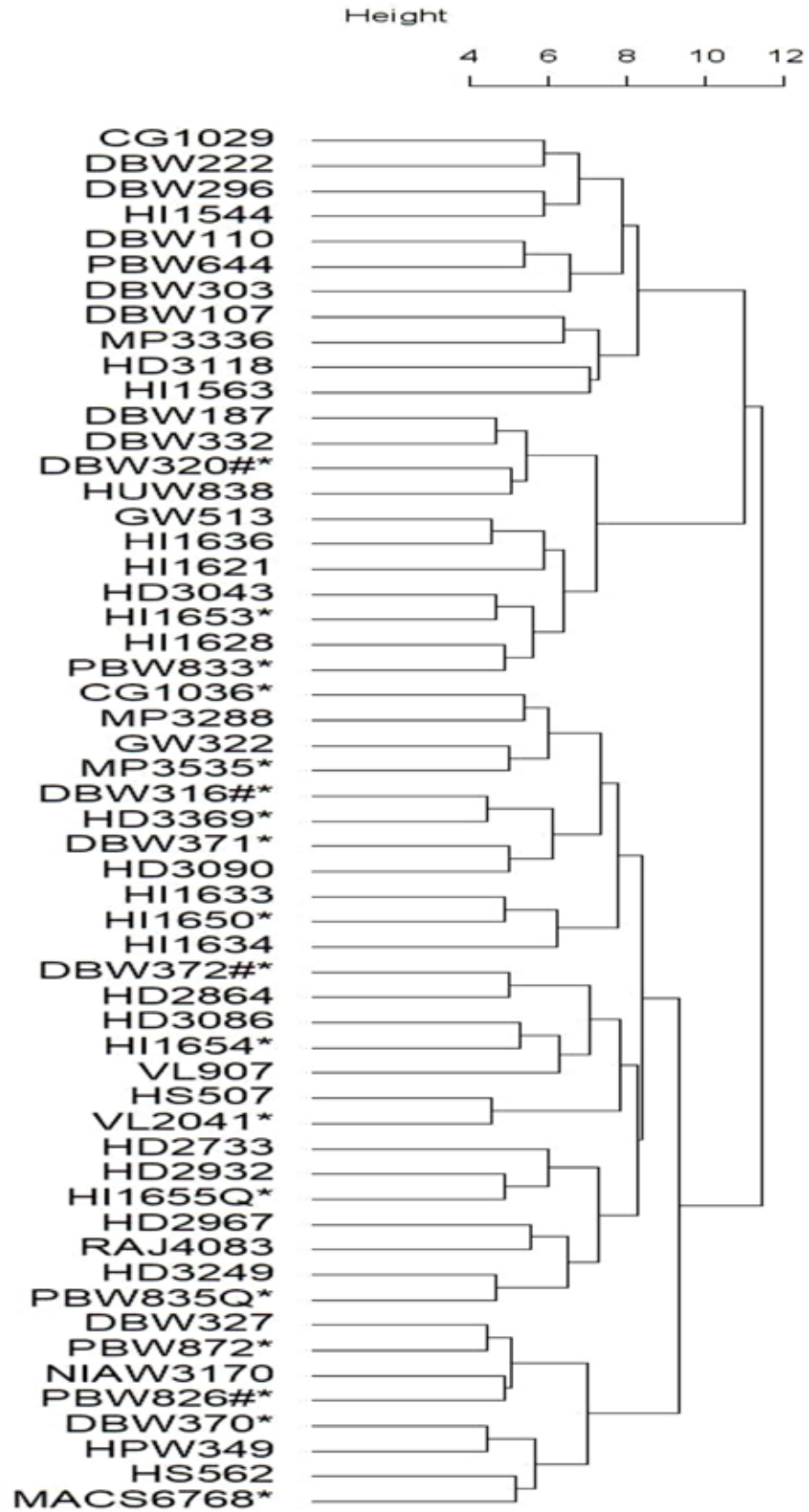

Fig. 4. Dendrogram using SSR and STS markers showing diversity among final year AVT Bread Wheat (*T. aestivum*) and check varieties