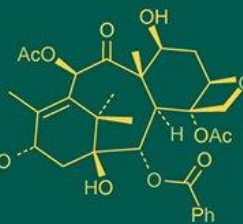
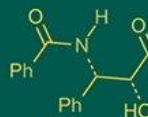


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Chidananda T
Department of Agricultural Botany (Genetics and Plant breeding), Dr. PDKV, Akola, Maharashtra, India

Dr. Manish M Wakode
Assistant Professor,
Department of Agricultural Botany, Dr. PDKV, Akola, Maharashtra, India

Dr. AG Deshmukh
Professor, Department of Molecular biology and Biotechnology, Dr. PDKV, Akola, Maharashtra, India

Dr. JP Khatod
Assistant Professor,
Department of Agricultural botany, Dr. PDKV, Akola, Maharashtra, India

Dr. NK Patke
Associate Professor,
Department of Agronomy, Dr. PDKV, Akola, Maharashtra, India

Dr. SK Burghate
Assistant professor,
Department of Agricultural botany, Dr. PDKV, Akola, Maharashtra, India

Yogesh BM
PG Scholar, Department of Agricultural botany (Genetics and Plant breeding), Dr. PDKV, Akola, Maharashtra, India

Suparna Sarkar
PG Scholar, Department of Agronomy, Dr. PDKV, Akola, Maharashtra, India

Corresponding Author:
Chidananda T
Department of Agricultural Botany (Genetics and Plant breeding), Dr. PDKV, Akola, Maharashtra, India

Genotype × environment interaction and stability of safed musli (*Chlorophytum borivillianum*) genotypes for yield and yield-related traits

Chidananda T, MM Wakode, AG Deshmukh, JP Khatod, NK Patke, SK Burghate, Yogesh BM and Suparna Sarkar

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Abstract

A multilocation experiment was conducted during Kharif 2025 to evaluate the performance, genotype × environment interaction and stability of eight safed musli (*Chlorophytum borivillianum*) genotypes across four environments, viz., Akola, Achalpur, Divthana and Pusad. The experiment was laid out in a Randomized Block Design with three replications at each environment. Significant variation among genotypes was observed for most of the growth, yield and yield-contributing traits. AKSM-01 recorded the highest pooled mean for fresh tuber yield (12.34 g plant⁻¹) and dry tuber yield (2.82 g plant⁻¹), along with superior performance for several yield-contributing traits. Environmental effects were also pronounced, with Achalpur recording the highest environmental mean for fresh and dry tuber yield. Significant genotype × environment interaction was observed for several traits, indicating differential responses of genotypes to environmental conditions. Stability analysis following the Eberhart and Russell model revealed that AKSM-08 exhibited a favourable combination of high mean performance, regression coefficient close to unity and low deviation from regression for fresh tuber yield (11.61 g plant⁻¹) and dry tuber yield (2.64 g plant⁻¹), indicating wider adaptation and stable performance across environments. AKSM-01, despite its superior yield, showed greater environmental sensitivity. Therefore, AKSM-08 was identified as a promising genotype for wider adaptation, while AKSM-01 may be useful for cultivation under favourable environments and as a potential source for further crop improvement.

Keywords: *Chlorophytum borivillianum*, genotype × environment interaction, multilocation testing, stability analysis, Eberhart and Russell, tuber yield, genotype performance

Introduction

Safed musli (*Chlorophytum borivillianum*; 2n = 4x = 28) is an important medicinal plant belonging to the family Liliaceae and is widely valued for its therapeutic and commercial significance. The genus *Chlorophytum* comprises several species distributed in tropical and subtropical regions, with *C. borivillianum* being one of the most economically important species in India (Bordia *et al.*, 1995) [1]. Its fasciculated storage roots are rich in bioactive constituents, particularly steroidal saponins, alkaloids, flavonoids, phenolics and polysaccharides, which contribute to its diverse pharmacological properties (Thakur *et al.*, 2009) [10]. Safed musli has been traditionally used in Ayurveda as a rejuvenating tonic or “Vajikarana Rasayana” and is reported to possess aphrodisiac, adaptogenic, antioxidant, immunomodulatory and antidiabetic properties (Deore and Khadabadi, 2009; Pal *et al.*, 2015) [2]. Increasing demand from pharmaceutical, nutraceutical and traditional medicine sectors has enhanced its economic importance, while several regions of India, including Maharashtra, possess favourable conditions for its cultivation (Singh *et al.*, 2008) [9]. Despite its increasing importance, productivity of safed musli is influenced by genetic variability and environmental conditions. Genotypes often differ in their response to environmental fluctuations, resulting in significant genotype × environment (G × E) interaction, which may alter the relative performance and ranking of genotypes across locations. Hence, multilocation testing under diverse environments is essential for identifying genotypes with high yield potential, wider adaptability and consistent performance.

Stability analysis provides a useful approach for understanding the response of genotypes to environmental variation and for identifying genotypes suitable for specific or wider adaptation. The Eberhart and Russell (1966) [4] model assesses phenotypic stability using the regression coefficient (b_i) and deviation from regression (S^2d_i), with genotypes exhibiting high mean performance, b_i close to unity and low S^2d_i generally considered desirable and stable. The applicability of this approach in safed musli has also been demonstrated by Dubey *et al.* (2017) [3] through evaluation of germplasm across different environments. Therefore, the present study was undertaken to evaluate safed musli genotypes across diverse environments, assess $G \times E$ interaction and stability for yield and yield-contributing traits, and identify superior and stable genotypes for use in crop improvement and wider cultivation.

Materials and Methods

The experiment was conducted during Kharif 2025 at four environments, viz., Nagarjuna Medicinal and Aromatic

Plants Garden, Dr. PDKV, Akola; Agricultural Research Station (ARS), Achalpur; Beetlevine Research Station (BRS), Divthana; and Agricultural Technology School (ATS), Pusad. Eight genotypes of safed musli (*Chlorophytum borivilianum*), namely AKSM-01, AKSM-08, AKSM-10, AKSM-11, AKSM-12, MCB-405, LC (Bordi Collection) and LC (Vivra Collection), were evaluated in a Randomized Block Design (RBD) with three replications at each environment. The genotypes were planted at a spacing of 30×10 cm, and the crop was sown during the second fortnight of June 2025. Observations were recorded for yield and yield-contributing traits at each environment. The data obtained from the multilocation trials were subjected to analysis of variance to determine the effects of genotypes, environments and genotype $\times$ environment interaction. Stability analysis was carried out following the Eberhart and Russell (1966) [4] model using the regression coefficient (b_i) and deviation from regression (S^2d_i) to identify genotypes with high mean performance, wider adaptability and stable performance across the environments.

Table 1: Mean values for Plant height and number of leaves per plant.

SN	Genotype	Plant height (cm)					Number of leaves per plant				
		Akola	Achalpur	Divthana	Pusad	Pooled	Akola	Achalpur	Divthana	Pusad	Pooled
1	AKSM 1	30.42	26.48	29.33	32.57	29.7	12.77	15.33	13.93	10.2	13.05
2	AKSM 8	25.42	27.25	24.6	31.77	27.25	10.17	13.33	12.57	11.91	11.99
3	AKSM 10	28.93	26.83	27.72	29.8	28.32	10.93	12.87	11.07	9.75	11.15
4	AKSM 11	26.93	26.33	26.43	31.3	27.75	9.53	12.53	11.07	8.65	10.44
5	AKSM 12	26	23.64	26.93	32.7	27.31	8.27	10.63	9.3	8.27	9.11
6	MCB 405	28.2	25.27	27.73	29.57	27.69	10.83	13.97	12.4	10.33	11.88
7	LC (Bordi collection)	23.83	22.07	23.37	32.63	25.47	9.3	12.4	11.47	7.77	10.23
8	LC (Vivra collection)	25.23	22.2	24.67	33.83	26.48	9.03	13.4	12.77	9.03	11.05
	GM	26.87	25	26.34	31.77		10.1	13.05	11.82	9.48	
	SE M ($\pm$)	0.942	0.76	0.637	0.537		0.627	0.348	0.588	0.588	
	CD at 5%	2.85	2.3	1.93	1.63		1.9	1.05	1.78	1.78	

Table 2: Mean values for Length of leaves and Width of leaves

SN	Genotype	Leaf Length (cm)					Width of leaves (cm)				
		Akola	Achalpur	Divthana	Pusad	Pooled	Akola	Achalpur	Divthana	Pusad	Pooled
1	AKSM 1	29.5	27.53	28.53	18.57	26.03	16.4	14.7	16.9	17.1	16.27
2	AKSM 8	23.27	25	25.67	16.8	22.68	15.93	14.43	16.13	15.8	15.57
3	AKSM 10	24.37	25.57	25.83	16.03	22.95	16.47	16.1	17.7	14.43	16.17
4	AKSM 11	26.67	25.3	26.13	17.2	23.82	14.97	16.77	13.83	16.2	15.44
5	AKSM 12	24.73	25.67	25.9	17.4	23.42	16.2	15.9	16.37	15.73	16.05
6	MCB 405	27.47	24.57	24.23	16.73	23.25	14.13	15.63	13.27	15.03	14.51
7	LC (Bordi collection)	22.9	23.37	23.47	17.93	21.91	13.37	11.37	15.9	16.3	14.23
8	LC (Vivra collection)	25.03	25.8	26.3	17.87	23.75	13.17	11.73	17.3	15.8	14.5
	GM	25.49	25.35	25.75	17.31		15.07	14.57	15.92	15.8	
	SE M ($\pm$)	0.714	0.63	0.646	0.383		0.299	0.283	0.35	0.325	
	CD at 5%	2.16	1.91	1.95	1.16		0.908	0.86	1.06	0.985	

Table 3: Mean values for Days to senescence and number of tubers per plant.

SN	Genotype	Days to 100% senescence of leaves					Number of tubers per plant				
		Akola	Achalpur	Divthana	Pusad	Pooled	Akola	Achalpur	Divthana	Pusad	Pooled
1	AKSM 1	116.67	90.67	113.33	96.33	104.2	12.16	12.08	12.39	11.28	11.97
2	AKSM 8	115	90.33	108	91.67	101.2	11.39	13.41	10.01	8.13	10.73
3	AKSM 10	112.67	89.67	107.67	85.67	98.92	8.39	11	8.79	8.4	9.14
4	AKSM 11	114.67	90.67	108.33	86	99.91	10.59	9	8.73	9.27	9.39
5	AKSM 12	116.33	93	109.67	95	103.5	8.32	9.94	7.19	8.87	8.57
6	MCB 405	112	92	106	86	99	9.47	10.29	8.89	10	9.66
7	LC (Bordi collection)	117.67	103.67	109	102.33	108.1	9.4	9.47	7.72	7.4	8.49
8	LC (Vivra collection)	113.67	101.67	107.67	102	106.2	9.24	10.27	8.67	8.8	9.24
	GM	114.84	93.96	108.71	93.12		9.86	10.68	9.04	9.01	
	SE M ($\pm$)	1.171	0.84	1.136	1.523		0.702	0.526	0.397	0.718	
	CD at 5%	3.55	2.54	3.44	4.619		2.12	1.59	1.2	2.17	

Table 4: Mean values for Length of tuber and Diameter of tuber.

Sr No	Genotype	Length of tuber (cm)					Diameter of tuber (mm)				
		Akola	Achalpur	Divthana	Pusad	Pooled	Akola	Achalpur	Divthana	Pusad	Pooled
1	AKSM 1	9.17	9.02	8.49	7.84	8.63	6.47	7.25	6.53	6.92	6.79
2	AKSM 8	7.4	8.45	5.76	6.39	6.99	5.93	7.1	6.31	6.47	6.45
3	AKSM 10	6.38	7.15	6.96	5.43	6.47	5.93	6.23	5.41	6.47	6
4	AKSM 11	6.33	5.95	6.97	5.03	6.07	5.87	6.29	6.33	6.13	6.15
5	AKSM 12	6.35	6.84	6.37	4.96	6.13	5.87	6.97	5.24	6.2	6.06
6	MCB 405	7.37	7.07	6.69	7.1	7.05	5	6.2	6.07	6.53	5.95
7	LC (Bordi collection)	7.83	6.49	7.06	6.53	6.97	5.6	7.4	6.43	6.07	6.37
8	LC (Vivra collection)	6.59	5.83	6.77	6.54	6.43	5.53	7.2	6.53	6.93	6.54
	GM	7.17	7.1	6.88	6.22		5.77	6.82	6.1	6.46	
	SE M (+)	0.424	0.493	0.406	0.315		0.202	0.262	0.285	0.182	
	CD at 5%	1.28	1.49	1.23	0.955		0.61	0.79	0.86	0.55	

Table 5: Mean values for Fresh tuber yield per plant and Diameter of tuber.

Sr No	Genotype	Fresh tuber yield (g/plant)					Dry tuber yield (g/plant)				
		Akola	Achalpur	Divthana	Pusad	Pooled	Akola	Achalpur	Divthana	Pusad	Pooled
1	AKSM 1	15.81	13.52	8.99	11.06	12.34	3.56	3.08	2.09	2.57	2.82
2	AKSM 8	12.38	14.42	9.85	9.8	11.61	2.74	3.29	2.28	2.28	2.64
3	AKSM 10	7.44	13.58	7.73	6.54	8.82	1.49	2.79	1.59	1.37	1.81
4	AKSM 11	10.92	9.75	8.76	7.41	9.2	2.3	2.07	1.85	1.52	1.93
5	AKSM 12	12.06	11.76	7.78	6.74	9.58	2.39	2.39	1.6	1.36	1.93
6	MCB 405	10.48	12.05	7.98	9.03	9.88	2.38	2.65	1.74	1.92	2.17
7	LC (Bordi collection)	12.73	14.13	9.95	7.39	11.05	2.66	2.96	2.11	1.58	2.32
8	LC (Vivra collection)	12.15	11.08	8.16	8.41	9.95	2.58	2.23	1.72	1.74	2.06
	GM	11.74	12.53	8.65	8.29		2.51	2.68	1.87	1.79	
	SE M (+)	1	0.917	0.5	0.762		0.23	0.21	0.13	0.16	
	CD at 5%	3.03	2.78	1.51	2.31		0.7	0.66	0.4	0.511	

Table 6: Mean values for Saponin content%.

Sr No	Genotype	Saponin content (%)				
		Akola	Achalpur	Divthana	Pusad	Pooled
1	AKSM 1	8.76	9.22	9.42	9.1	9.12
2	AKSM 8	8.69	9.41	8.12	9.14	8.84
3	AKSM 10	8.2	9.6	8.16	8.6	8.64
4	AKSM 11	9.37	8.8	9.12	9.21	9.12
5	AKSM 12	9.6	9.09	8.8	8.8	9.07
6	MCB 405	8.64	8.7	8.16	9.6	8.77
7	LC (Bordi collection)	7.95	8.21	8.41	8.31	8.22
8	LC (Vivra collection)	9.03	8.72	8.96	8.86	8.89
	GM	8.78	8.96	8.64	8.95	
	SE M (+)	0.3	0.24	0.28	0.22	
	CD at 5%	0.92	0.73	0.85	0.69	

Table 7: Bartlett's test for homogeneity of error variances for different characters across four environments

Character	Bartlett's χ^2 statistic	P-value	Inference
Plant height(cm)	4.716	0.1938	NS; error variances are homogeneous
Number of leaves per plant	5.0522	0.168	NS; error variances are homogeneous
Leaf Length (cm)	5.2837	0.1522	NS; error variances are homogeneous
Width of leaves(cm)	0.7003	0.8731	NS; error variances are homogeneous
Days to 100% senescence of leaves	4.6683	0.1978	NS; error variances are homogeneous
Number of tubers per plant	5.7356	0.1252	NS; error variances are homogeneous
Length of tuber(cm)	2.6881	0.4423	NS; error variances are homogeneous
Diameter of tuber(mm)	3.5737	0.3113	NS; error variances are homogeneous
Fresh tuber yield (g/plant)	6.6457	0.0841	NS; error variances are homogeneous
Dry tuber yield (g/plant)	4.94	0.17	NS; error variances are homogeneous
Saponin content (%)	1.388	0.708	NS; error variances are homogeneous

Table 8: Pooled analysis of variance for genotype x environment interactions for different traits in safed musli.

Sources	Df	Plant height (cm)	Number of leaves	Leaf Length (cm)	Width of leaves (cm)	Days to 100% senescence of leaves	Number of tubers per plant	Length of tuber (cm)	Diameter of tuber (mm)	Fresh tuber yield (g/plant)	Dry tuber yield (g/plant)	Saponin Content (%)
		1	2	3	4	5	6	7	8	9	10	11
Genotypes	7	6.19**	5.92**	5.76**	2.71*	47.63**	5.46**	2.67**	0.35	6.08*	0.521**	0.365*
Env. + (G×E)	24	11.39	3.12	17.77	2.26	128.6	1.35	0.53	0.33	6.2	0.27	0.18
Environments (Linear)	1	209.32	63.50	399.22	9.60	2811.26	14.98	4.47	4.95	110.53	4.82	0.54
G × E (Linear)	7	6.28**	0.70*	1.4	4.53**	27.61**	1.21**	0.29	0.11	0.88	0.029	0.268**
Pooled Error	56	0.54	0.3	0.36	0.09	1.42	0.36	0.17	0.05	0.66	0.037	0.07
Pooled Deviation	16	1.25*	0.41	1.09**	0.81**	5.11**	0.56	0.39*	0.14**	2.01**	0.095**	0.122

*, ** Significant at 5% and 1% level of significant

Table 9: Estimation of environmental index for all eleven characters

Sources	Df	Plant height (cm)	Number of leaves	Leaf Length (cm)	Width of leaves (cm)	Days to 100% senescence of leaves	Number of tubers per plant	Length of tuber (cm)	Diameter of tuber (mm)	Fresh tuber yield (g/plant)	Dry tuber yield (g/plant)	Saponin Content (%)
		1	2	3	4	5	6	7	8	9	10	11
Genotypes	7	6.19**	5.92**	5.76**	2.71*	47.63**	5.46**	2.67**	0.35	6.08*	0.521**	0.365*
Env. + (G×E)	24	11.39	3.12	17.77	2.26	128.6	1.35	0.53	0.33	6.2	0.27	0.18
Environments (Linear)	1	209.32	63.50	399.22	9.60	2811.26	14.98	4.47	4.95	110.53	4.82	0.54
G × E (Linear)	7	6.28**	0.70*	1.4	4.53**	27.61**	1.21**	0.29	0.11	0.88	0.029	0.268**
Pooled Error	56	0.54	0.3	0.36	0.09	1.42	0.36	0.17	0.05	0.66	0.037	0.07
Pooled Deviation	16	1.25*	0.41	1.09**	0.81**	5.11**	0.56	0.39*	0.14**	2.01**	0.095**	0.122

Table 10: Stability parameters (mean, bi, S²di).

Sr No	Genotype	Plant height (cm)			Number of leaves per plant			Leaf Length (cm)			Width of leaves (cm)		
		Mean	bi	S ² di	Mean	bi	S ² di	Mean	bi	S ² di	Mean	bi	S ² di
1	AKSM 1	29.7	0.77*	1.25 *	13.05	1.25	0.52	26.03	1.22	0.3	16.27	1.59	0.16
5	AKSM 8	27.25	0.89**	4.30**	11.99	0.62	0.86 *	22.68	0.96	1.1263 *	15.57	1	0.19
6	AKSM 10	28.32	0.39	-0.010	11.15	0.72	0.08	22.95	1.12	0.32	16.17	0.05	2.6231 **
7	AKSM 11	27.75	0.79	-0.238	10.44	1.04	-0.27	23.53	1.04	0.8071 *	15.44	-1.22	1.5643 **
8	AKSM 12	27.31	1.27	0.308	9.11	0.66**	-0.19	23.42	0.98	0.07	16.05	0.09	0.01
10	MCB 405	27.69	0.52	0.711	11.88	1	-0.27	23.08	1.04	3.3906 **	14.51	-1.03	0.8684 **
11	LC (Bordi collection)	25.47	1.62	-0.091	10.23	1.26	-0.05	21.91	0.65**	-0.24	14.23	3.6	0.09
12	LC (Vivra collection)	26.48	1.71	-0.512	11.05	1.39	0.24	23.75	0.96	0.01	14.5	3.9	0.2259 *
	Mean	27.50			11.11			23.42			15.34		

Table 11: Stability parameters (mean, bi, S²di).

Sr No	Genotype	Days to 100% senescence of leaves			No. of tubers per plant			Length of tuber (cm)			Diameter of tuber (mm)		
		Mean	bi	S ² di	Mean	bi	S ² di	Mean	bi	S ² di	Mean	bi	S ² di
1	AKSM 1	104.25	1.13	13.10 **	11.97	0.18	-0.04	8.63	1.362	-0.147	6.79	0.78	-0.04
5	AKSM 8	101.25	1.12*	-0.131	10.73	2.65*	0.45	6.99	1.493	1.298**	6.45	1.03	-0.03
6	AKSM 10	98.91	1.21*	2.361	9.14	1.29	0.4	6.47	1.443	0.143	6.00	0.56	0.1594 *
7	AKSM 11	99.91	1.26*	2.344	9.39	0.17	0.62	6.07	1.309	0.329	6.15	0.29**	-0.01
8	AKSM 12	103.5	1.04	0.654	8.57	1.07	0.53	6.13	1.762	-0.0563	6.06	1.23	0.2499 **
10	MCB 405	99	1.09	5.173 *	9.66	0.45	0.01	7.05	0.119	-0.0589	5.95	1.13	0.2053 *
11	LC (Bordi collection)	108.16	0.61**	5.132 *	8.49	1.25	-0.06	6.97	0.787	0.237	6.37	1.43	0.1828 *
12	LC (Vivra collection)	106.25	0.51**	0.896	9.24	0.89	-0.32	6.43	-0.278	0.0605	6.54	1.52	0.02
	Mean	102.65			9.66			6.84			6.54		

Table 12: Stability parameters (mean, bi, S2di).

Sr No	Genotype	Fresh tuber yield (g/plant)			Dry tuber yield (g/plant)			Saponin content (%)		
		Mean	bi	S2di	Mean	bi	S2di	Mean	bi	S2di
1	AKSM 1	12.34	1.13	3.5061 **	2.82	1.15	0.16**	9.12	-0.39	0.039
5	AKSM 8	11.61	1	-0.25	2.64	1	0.0003	8.84	3.67**	-0.053
6	AKSM 10	8.82	1.08	6.6692 **	1.81	1.04	0.29**	8.64	3.36	0.21*
7	AKSM 11	9.2	0.58	0.31	1.93	0.62	0.011	9.12	-0.62	0.002
8	AKSM 12	9.58	1.23	-0.16	1.93	1.16	-0.022	9.05	-0.27	0.138
10	MCB 405	9.88	0.76	0.0025	2.17	0.89	-0.018	8.77	3.1	0.141
11	LC (Bordi collection)	11.05	1.33	0.46	2.32	1.3	0.009	8.22	-0.17	-0.0132
12	LC (Vivra collection)	9.95	0.84	0.19	2.06	0.8	0.0263	8.89	-0.66**	-0.058
	Mean	10.30			2.21			8.83		

Table 13: Nature of Stability of Safed musli genotypes under different environment.

Sr. No.	Character	Average stability (suitable for all environments)	Below-average stability, bi > 1 (suitable for favourable environment)	Above-average stability, bi < 1 (suitable for unfavourable environment)
1	Plant height (cm)	—	AKSM 12, LC (Bordi Collection), LC (Vivra Collection)	AKSM 10, AKSM 11, MCB 405
2	Days to 100% senescence of leaves	AKSM 12	AKSM 8, AKSM 10, AKSM 11	LC (Vivra Collection)
3	Number of leaves per plant	AKSM 11, MCB 405	AKSM 1, LC (Bordi Collection), LC (Vivra Collection)	AKSM 10, AKSM 12
4	Length of leaves (cm)	AKSM 12, LC (Vivra Collection)	AKSM 1, AKSM 10	LC (Bordi Collection)
5	Width of leaves (cm)	AKSM 8	AKSM 1, LC (Bordi Collection)	AKSM 12
6	Number of tubers per plant	—	AKSM 8, AKSM 10, AKSM 12, LC (Bordi Collection)	AKSM 1, AKSM 11, MCB 405, LC (Vivra Collection)
7	Fresh tuber yield (g/plant)	AKSM 8	AKSM 12, LC (Bordi Collection)	AKSM 11, MCB 405, LC (Vivra Collection)
8	Dry tuber yield (g/plant)	AKSM 8	AKSM 12, LC (Bordi Collection)	AKSM 11, MCB 405, LC (Vivra Collection)
9	Diameter of tuber (mm)	AKSM 8	LC (Vivra Collection)	AKSM 1, AKSM 11
10	Length of tuber (cm)	—	AKSM 1, AKSM 10, AKSM 11, AKSM 12	MCB 405, LC (Bordi Collection), LC (Vivra Collection)
11	Saponin content (%)	—	AKSM 8, MCB 405	AKSM 1, AKSM 11, AKSM 12, LC (Bordi Collection), LC (Vivra Collection)

Results and Discussion

Genotypic performance and variability

The pooled analysis revealed considerable variation among the eight safed musli genotypes for growth, yield and quality traits (Tables 1-6). AKSM-01 recorded the highest pooled plant height (29.70 cm), number of leaves per plant (13.05), leaf length (26.03 cm), number of tubers per plant (11.97), tuber length (8.63 cm), tuber diameter (6.79 mm), fresh tuber yield (12.34 g plant⁻¹) and dry tuber yield (2.82 g plant⁻¹). The highest pooled saponin content was recorded in AKSM-01 and AKSM-11 (9.12%), followed by AKSM-12 (9.07%). These results indicated substantial genetic variation among the genotypes, providing scope for selection of superior material for yield and quality improvement.

The environments also differed considerably in their influence on trait expression. Achalpur recorded the highest environmental mean for fresh tuber yield (12.53 g plant⁻¹) and dry tuber yield (2.68 g plant⁻¹), whereas Divthana recorded the lowest means (8.65 and 1.87 g plant⁻¹, respectively). The environmental indices further indicated that Achalpur was favourable for fresh and dry tuber yield, while Divthana and Pusad were comparatively less favourable environments (Table 9). Such environmental

variation provided an appropriate basis for evaluating genotype × environment interaction.

Genotype × environment interaction

Bartlett's test revealed non-significant differences among error variances for all eleven traits, indicating homogeneity of error variances across the four environments (Table 7). The pooled analysis of variance showed significant differences among genotypes for most of the characters, confirming the presence of genetic variability (Table 8). Significant environmental effects were observed for several traits, particularly plant height, leaf length, days to senescence and fresh tuber yield.

The genotype × environment interaction was significant for plant height, number of leaves, leaf width, days to senescence, number of tubers per plant and saponin content, indicating differential responses of genotypes to environmental conditions. Significant pooled deviation from regression for several traits, including fresh and dry tuber yield, further indicated the presence of non-linear genotype × environment interaction. The results emphasize the importance of multilocation testing for identifying genotypes with consistent performance. Similar importance of genotype × environment interaction and stability analysis in safed musli has been reported by Dubey *et al.* (2017) [3].

The Eberhart and Russell model separates the environmental response into linear and non-linear components through the regression coefficient and deviation from regression.

Stability analysis

Stability parameters revealed considerable differences among genotypes for their response to environmental variation (Tables 10-12). According to the Eberhart and Russell model, a genotype with high mean performance, regression coefficient (b_i) close to unity and low deviation from regression (S^2d_i) is considered desirable for wider adaptation. Genotypes with $b_i > 1$ are generally more responsive to favourable environments, whereas genotypes with $b_i < 1$ show better adaptation to unfavourable environments.

For fresh tuber yield, AKSM-01 recorded the highest mean ($12.34 \text{ g plant}^{-1}$), but its significant S^2d_i (3.5061^{**}) indicated considerable environmental sensitivity. In contrast, AKSM-08 recorded a high mean yield of $11.61 \text{ g plant}^{-1}$ with $b_i = 1.00$ and very low S^2d_i (-0.25), indicating desirable average stability across environments. For dry tuber yield, AKSM-08 again showed a favourable combination of high mean ($2.64 \text{ g plant}^{-1}$), $b_i = 1.00$ and near-zero deviation from regression (0.0003). Thus, AKSM-08 was identified as the most promising genotype for stable fresh and dry tuber yield across the tested environments.

For individual component traits, AKSM-01 showed superior performance for several yield-contributing characters, while AKSM-08 exhibited comparatively better stability for number of leaves, leaf width and tuber yield. AKSM-12 showed desirable stability for days to senescence and leaf length. MCB-405 showed comparatively low environmental responsiveness for some traits, suggesting its usefulness under less favourable conditions.

The present findings are in agreement with earlier reports in safed musli. Maiti and Geetha (2005) ^[7] reported wide genetic variability among *Chlorophytum borivillianum* germplasm for plant type, maturity, growth and yield characters, as well as size and shape of fleshy roots. Kothari and Singh (2001) ^[5] also observed considerable variability among safed musli germplasm accessions for growth and yield-related traits. Similarly, Kumar *et al.* (2007) ^[6] reported significant variation among genotypes and substantial genetic variability for yield and its contributing characters in safed musli. Further, significant genotype $\times$ environment interaction and differential stability of genotypes for quantitative traits have been reported by Dubey *et al.* (2017) ^[3], supporting the importance of multilocation evaluation for identifying stable and widely adapted genotypes.

Overall performance and stability

Considering mean performance together with b_i and S^2d_i , AKSM-08 was identified as the most desirable genotype for wider adaptation, particularly for fresh and dry tuber yield. Although AKSM-01 recorded the highest fresh and dry tuber yield, its significant deviation from regression indicated greater environmental sensitivity. Therefore, AKSM-01 may be considered a high-yielding genotype particularly suited to favourable environments, whereas AKSM-08 combined good yield with greater stability across environments. These genotypes may therefore serve as promising material for further evaluation and utilization in safed musli improvement programmes.

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