Indian Journal of Ecology (2023) 50(4): 1078-1085
DOI: https://doi.org/10.55362/IJE/2023/4016

Manuscript Number: 4016
NAAS Rating: 5.79

Stability of Valepotriate Specific Valerian Chemotypes using Eberhart and Russell, AMMI, BLUP, WAAS and MTSI

Neha Mishra, Rakesh Kumar Gupta, Ashu Chandel and Subhash Sharma[1]

Department of Basic Sciences, [1]Department of Social Sciences
Dr YSP University of Horticulture and Forestry Nauni, Solan -173 230, India
E-mail: mneha6893@gmail.com

***Abstract*:** Due to over-exploitation of *Valeriana jatamansi* rhizomes this species is now on the verge of extinction in India. For sustainable production and supply to the market/herbal industries, present study was conducted on twenty one chemotypes for four years, considering the four valepotriates. Analysis of variance based on Eberhart and Russell, additive multiplicative mean interaction was performed for all the valepotriates, which indicated highly significant Chemotype × Environment interaction for the valepotriates valtrate, acevaltrate, didrovaltrate, IVHD valtrate. The chemotypes A/F/38, D/B/10, D/B/15, U/B/1 were superior for valtrate and for acevaltrate the stable chemotypes were A/B/31, D/B/5, A/F/38, A/F/15, D/B/16, D/F/19. For didrovaltrate A/B/31, A/F/38, D/F/19, D/B/13 these four chemotypes are identified as superior and highly stable chemotypes. Seven chemotypes namely A/B/7, A/F/8, A/B/40, U/B/46, U/B/1, D/B/16 and A/B/42 were superior and highly stable chemotypes for IVHD valtrate. The three chemotypes namely A/B/31, A/B/42 and U/B/1 were superior and stable for all the valepotriates. The stable valepotriate specific chemotypes could be used for valerian varietal development programme and could ensure the preservation of the species

Keywords: Indian Valerian, Valepotriates, Stability analysis, Superior chemotypes

Valeriana jatamansi Jones is a temperate medicinal plant native to the Himalayas and found from Afghanistan to southwest China, India, Nepal, Bhutan, and Myanmar at elevations ranging from 1,000 to 3,000 meters above sea level (Jugran et al 2013). This herb, which belongs to the family Valeriaceae, was first mentioned in the 9th century by an Indian physician under the common name Indian Valerian, which is derived from the word Velo, which means "powerful drug." Although the term "Valerian" comes from the Latin word "valere," which means having aromatic or clinical properties (Bhatt et al 2012). This is a preferred sedative herb over modern medications, and can sometimes enhance the therapeutic effects of other generic drugs (Rivera et al. 2013, Jugran et al 2019). The presence of valepotriates in valerian roots/rhizome is responsible for the sedative and tranquillizing properties. These potent medicinal properties are concentrated in the herb's underground parts, such as rhizomes and roots, rather than the plant's aboveground biomass.

V. jatamansi has been collected from forests for decades, as have other Himalayan herbs, and overexploitation is causing this herb to disappear from its natural habitat. The IUCN, however, has not yet designated this herb as endangered. If this herb is not protected, it will become extinct very soon. As a result, there is an urgent need for this species' replenishment and cultivation. This species chemical diversity, in addition to its genetic diversity, has been documented (Mathela and Dev 2003, Sati et al 2005, Raina and Negi 2015). Knowledge of chemically stable genotypes (Stable chemotypes) can be applied in crop breeding programmes for varietal development, which is important in commercial cultivation of the species. The Additive Multiplicative Mean Interaction (AMMI) model has been the most commonly used (Jain et al 2017) so far for capturing chemotype and environment interaction regression models. WAAS (Weighted Average of Absolute Scores) was recently used in the AMMI I biplot instead of the first PC to obtain the entire G x E interaction variance.

Linear Mixed-effects Models (LMM) include a prediction component called Best Linear Unbiased Predictor (BLUP), which predicts a genotype's performance in a given environment. Weighting between Weighted Average Absolute Scores from BLUP (WASSB) and mean value (Y) allows for the selection of yield and stability at the same time via a superior index called WASSBY (Olivoto et al 2019a). Throughout the most situations, genotype stability is assessed using a single trait. The selection of a stable superior genotype for a greater number of traits is required in combination breeding. MTSI (Multi Trait Stability Index) identifies stable genotypes by taking into account all traits (Olivoto et al 2019b). In this paper, these analyses are used to find out the chemotypic stability of Valerian chemotypes

and selection of stable superior chemotypes based on various Valepotriates for four years evaluation.

MATERIAL AND METHODS

The Department of Medicinal and Aromatic Plants conducted the experiment in Medicinal and Aromatic Plants Research Farm, Shilly, Distt. Solan, at an altitude of 1550m amsl. The geographical coordinates of the research field are latitude-N 30^0 54´ 30´´ and longitude E 77^0 07´ 30´´ Himachal Pradesh India. Plants (400-500) of different germplasms uniformly kept under the same climatic condition at Shilly farm were critically observed for different morphological features viz plant habit, type of leaf stem and root, inflorescence type and floral characteristics for quantitative assessment of distinct valepotriates from the roots of *V. jatamansi*. Plants with at least one distinguishing morphological feature were labelled and named A/B/7, U/B/1, U/F/8, and so on. Because the species is gynodioecious the first letter indicates the parent germplasm, the second indicates the plant sex (female, bisexual), and the third number indicates the plant's serial number (Raina and Srivastava 1992). A four-year quantitative study of the distinct valepotriates extracted from rhizomes of *Valeriana jatamansi* chemotypes, namely valtrate, acevaltrate, didrovaltrate, and isovaleroxyhydroxyldidro valtrate (IVHD valtrate), was conducted for four years, 2015 to 2018.

Eberhart and Russell model: Linear regression was performed using the Eberhart and Russell method. The pooled analysis of variance over the four years was done to test the chemotype(C) and the environment (E) differences against the C x E interactions for all the Valepotriates under study.

Additive multiplicative mean interaction model (AMMI): The recorded data were subjected to the AMMI analysis according to the statistical model provided by (Zobel et al1988).

Weighted average absolute scores (WAAS): The sum of squares for the C×E interaction was decomposed into single values. The IPCAs of C×E interaction from AMMI ANOVA were used to calculate Weighted Average Absolute Scores (WAAS). WAAS took the place of IPCA1 in the traditional AMMI1 biplot (Olivoto et al 2019a).

Best linear unbiased predictor (BLUP): BLUP is a prevalent method that uses a linear mixed model and treats chemotype effect as random. The components of variance were estimated using restricted maximum likelihood (Dempster et al 1977). To determine the significance of C×E and chemotype, the likelihood ratio test was used (Random effects). The chemotype's BLUP is the sum of the general mean across the chemotypic effect and the environments.

Multi trait stability index (MTSI): MTSI is calculated using factor analysis scores and the genotype-ideotype distance (Euclidian) (Olivoto et al 2019b). MTSI was computed using all valepotriates and the final loadings were calculated using the Varimax rotation criterion. WAASBY means were used to calculate the chemotype scores. The ideotype scores were calculated using the assumption that an ideotype has the highest WAASBY values (100) for all observed traits.

Software: An open-source software R 4.2.0 was used for performing all the statistical analysis utilizing package 'metan' developed by Olivoto (2019).

RESULT AND DISCUSSION

Eberhart and Russell stability model: This model was used to identify the stable chemotypes among the high valepotriates content rich chemotype by partitioning the C×E interaction into two parts (Eberhart and Russell 1966). Significant variance due to chemotypes, environment, chemotype × environment indicated the presence of variation in the mean performance of all the chemotypes over different environment and in the environment mean. C×E interaction variance was significant that suggested the differential performance of chemotypes under varying environment (Table 1). The data on the three stability parameters, i.e., phenotypic index (P_i), regression coefficient (b_i) and deviation from regression (σ^2_{di}) for different valepotriates are presented in Error: Reference source not found and the stable chemotypes for different valepotriates are presented in Table 3.

AMMI model analysis: The result of AMMI ANOVA showed that the chemotype, environment and C × E interaction effects were highly significant for the various valepotriates (Table 4). A high environment effect of 22.30% of the total sum of squares was observed for Didrovaltrate followed by IVHD valtrate (19.82%), valtrate (11.99%), acevaltrate (7.94%). Medium chemotype effect was observed for valtrate (33.70% of the total sum of squares) while high chemotype effect was observed for acevaltrate (57.25%). The interaction effect (C× E) ranged from medium (22.71%) for didrovaltrate to high (53.65%) for valtrate. The C× E was further partitioned into Interaction Principal Component Axes (IPCA) and residuals. The partitioning of C× E shows that the top three interaction principal component analysis (IPCA) scores from the AMMI model best represents the C× E patterns for valepotriates.

Weighted average absolute scores (WAAS) plot: WAAS plots mean values versus WAAS scores, with mean values on the X-axis and WAAS scores on the y-axis. WAAS is regarded as one of the most effective and efficient tools for identifying superior and stable genotypes (Abdelghany et al

2021). The WAAS index computed using GEI variance is used to estimate stability in this model (Olivoto et al. 2019b). Quadrant I (unstable), Quadrant II (unstable), Quadrant III (stable), and Quadrant IV (stable) comprise the WAAS plot (Fig. 1). Quadrant IV is the most preferred quadrant for selecting stable and superior genotypes, whereas genotypes from Quadrant III are stable but low yielders. Quadrants I and II, on the other hand, are made up of unstable but high-yielding genotypes. If the WAAS values of the genotypes are close to zero, the genotype is considered most stable (Olivoto et al. 2019b). The WAAS biplot for valtrate represents A/F/38, D/B/15, U/B/1 as the most stable chemotypes having WAAS values near to zero. The WAAS biplot of acevaltrate represented D/B/5, A/F/38, A/F/15, D/F/19 and U/F/6. The chemotypes having mean value greater than 0.5 and WAAS value near to zero was A/B/31 is considered as stable and better performing chemotype for acevaltrate. The chemotypes A/F/38, D/F/19, A/B/31 and D/B/13 are considered as stable and better performing chemotypes for didrovaltrate. The WAAS biplot for IVHD valtrate represents A/B/7, A/F/8, A/B/40, U/B/46, U/B/1 as the stable chemotypes. The chemotypes D/B/16 and A/B/42 are considered as stable and better performing chemotypes for IVHD valtrate (Fig. 1).

Table 1. Pooled analysis of variance for the valepotriates content estimated from the rhizomes of higher yielder chemotypes

Source of variation	d.f.	MSS			
		Rhizome valtrate	Rhizome acevaltrate	Rhizome didrovaltrate	Rhizome IVDH valtrate
Chemotype	20	0.571	0.030	0.437	0.553
Environment	3	1.354	0.027	1.188	1.634
C × E	60	0.303	0.006	0.061	0.142
Environment + C × E	63	0.353	0.007	0.114	0.213
Environment(linear)	1	4.063	0.082	3.565	4.902
C × E (linear)	20	0.411	0.011	0.086	0.205
Pooled deviation	42	0.237	0.003	0.046	0.105
A/B/7	2	0.150	0.003	0.023	0.102
A/B/31	2	0.034	0.002	0.008	0.050
A/B/33	2	0.538	0.011	0.367	1.436
A/B/40	2	0.146	0.000	0.001	0.006
A/B/42	2	1.217	0.002	0.030	0.028
A/F/8	2	0.048	0.001	0.012	0.018
A/F/10	2	0.064	0.002	0.050	0.076
A/F/15	2	0.129	0.001	0.084	0.191
A/F/36	2	1.319	0.019	0.128	0.043
A/F/38	2	0.079	0.004	0.010	0.006
D/B/5	2	0.007	0.001	0.001	0.007
D/B/10	2	0.184	0.000	0.016	0.004
D/B/13	2	0.065	0.000	0.006	0.006
D/B/15	2	0.087	0.001	0.117	0.059
D/B/16	2	0.065	0.002	0.061	0.065
D/F/9	2	0.223	0.005	0.003	0.024
D/F/19	2	0.259	0.002	0.008	0.001
U/B/1	2	0.199	0.001	0.000	0.050
U/B/46	2	0.156	0.000	0.003	0.024
U/F/6	2	0.009	0.005	0.003	0.004
U/F/47	2	0.003	0.001	0.026	0.011
Pooled error	168	0.001	0.000	0.000	0.002
Total	251				

Table 2. Stability parameters for different valepotriates contents estimated from the rhizomes of high yielder **c**hemotypes

Chemotypes	Valtrate				Acevaltrate			
	Mean	b_i	P_i	σ^2_{di}	Mean	b_i	P_i	σ^2_{di}
A/B/7	1.395	-1.108	0.055	0.148	0.294	-1.38	0.146	0.003
A/B/31	1.218	0.913	-0.122	0.032	0.358	0.90	0.210	0.001
A/B/33	1.506	5.322	0.166	0.537	0.260	7.28	0.112	0.011
A/B/40	1.124	1.629	-0.216	0.144	0.054	0.48	-0.094	0.000
A/B/42	2.247	1.476	0.907	1.215	0.088	1.01	-0.060	0.002
A/F/8	1.060	0.230	-0.280	0.046	0.107	1.27	-0.040	0.000
A/F/10	1.221	-0.048	-0.119	0.063	0.116	-0.71	-0.032	0.002
A/F/15	1.074	3.044	-0.266	0.127	0.178	2.42	0.030	0.001
A/F/36	2.291	2.101	0.952	1.317	0.194	2.49	0.046	0.019
A/F/38	1.474	0.131	0.134	0.078	0.188	0.66	0.040	0.004
D/B/5	1.115	0.900	-0.225	0.005	0.175	1.18	0.027	0.001
D/B/10	1.342	1.293	0.002	0.183	0.044	0.64	-0.104	0.000
D/B/13	0.985	0.324	-0.355	0.064	0.037	0.36	-0.110	0.000
D/B/15	1.524	-0.461	0.184	0.086	0.060	0.04	-0.088	0.001
D/B/16	0.906	0.970	-0.434	0.064	0.148	1.10	0.001	0.002
D/F/9	1.199	0.149	-0.141	0.221	0.149	0.58	0.001	0.005
D/F/19	1.526	-1.223	0.186	0.258	0.161	-0.30	0.013	0.002
U/B/1	1.706	0.718	0.366	0.198	0.066	0.47	-0.082	0.001
U/B/46	1.219	2.380	-0.121	0.155	0.062	0.29	-0.086	0.000
U/F/6	0.896	0.593	-0.444	0.007	0.221	1.95	0.073	0.005
U/F/47	1.110	1.667	-0.230	0.002	0.145	0.28	-0.003	0.001
A/B/7	0.286	0.022	-0.299	0.022	0.991	0.33	0.26	0.101
A/B/31	0.628	1.119	0.042	0.007	0.722	0.54	-0.01	0.048
A/B/33	0.625	1.415	0.039	0.367	1.502	3.68	0.77	1.434
A/B/40	0.170	0.327	-0.416	0.000	1.014	1.71	0.28	0.004
A/B/42	0.663	1.495	0.078	0.030	0.859	1.12	0.12	0.026
A/F/8	0.480	0.515	-0.106	0.012	0.872	0.58	0.14	0.016
A/F/10	0.504	0.440	-0.081	0.050	0.481	0.13	-0.25	0.074
A/F/15	0.647	1.303	0.061	0.084	1.235	2.59	0.50	0.189
A/F/36	1.360	2.968	0.774	0.128	0.579	0.98	-0.16	0.041
A/F/38	0.760	1.106	0.174	0.010	0.281	0.29	-0.45	0.005
D/B/5	0.445	0.719	-0.140	0.001	0.471	0.78	-0.26	0.005
D/B/10	0.411	0.879	-0.174	0.016	0.167	0.25	-0.57	0.002
D/B/13	0.726	1.271	0.141	0.006	0.488	0.44	-0.25	0.004
D/B/15	1.416	2.200	0.830	0.117	0.502	0.49	-0.23	0.058
D/B/16	0.368	0.769	-0.218	0.061	0.938	1.29	0.20	0.064
D/F/9	0.278	0.116	-0.308	0.003	0.505	0.20	-0.23	0.022
D/F/19	0.856	1.209	0.271	0.008	0.362	0.30	-0.37	-0.001
U/B/1	0.233	0.301	-0.352	0.000	1.406	1.75	0.67	0.048
U/B/46	0.198	0.290	-0.387	0.003	1.099	2.39	0.36	0.022
U/F/6	0.548	1.038	-0.038	0.003	0.510	0.56	-0.23	0.002
U/F/47	0.695	1.499	0.110	0.025	0.458	0.60	-0.28	0.009

LMM-Best linear unbiased predictor: The chemotype (C) and C × E variances were significant for all the valepotriates based on likelihood ratio test (Table 5). The contribution of environment variation was high for Acevaltrate (42.86%) followed by Didrovaltrate (36.51%). The coefficient of determination (R^2_{CEI}) of G × E interaction was found to be moderate to low.

The accuracy of selection was very high for the valepotriates didrovaltrate (0.93) followed by acevaltrate. High selection accuracy was found for IVHD valtrate (0.86) and moderate accuracy was observed for valtrate (0.68). The genotypic correlation among environments (r_{Ce}) was high for Valtrate (0.84), IVHD Valtrate (0.65) while was low for Didrovaltrate (0.32) and Acevaltrate (0.30).

The predicted mean values of the chemotypes are presented in Figure 2. Eight chemotypes had above-average predicted mean value for valtrate. A/F/36 followed by A/B/42, U/B/1 and D/F/19 had the highest predicted mean values for valtrate. Out of 11 chemotypes that had above-average predicted mean value, A/B/31 followed by A/B/7 had the highest predicted means for acevaltrate. Similarly, 10 chemotypes for didrovaltrate, 11 chemotypes for IVHD

Table 3. Stability of various chemotypes over different years for different valepotriates

Valepotriates	Suitable For				
	Rich environment		Poor environment		Stable
	Below average stability	Above average stability	Below average stability	Above average stability	
Valtrate	A/B/33, A/B/42, A/F/36,	A/B/7, A/F/38, D/B/15, D/F/19,	A/B/40, A/F/15, U/B/46, U/F/47	A/B/31, A/F/8, A/F/10, D/B/5, D/B/13, D/B/16, D/F/9, U/F/6	D/B/10, U/B/1,
Acevaltrate	A/B/33, A/F/36, U/F/6,	A/B/7, A/B/40, A/F/15, A/F/38, D/F/9, D/F/19	A/B/42, A/F/8, U/F/47	A/F/10, D/B/10, D/B/13, D/B/15, U/B/1, U/B/46,	A/B/31, D/B/5, D/B/16,
Didrovaltrate	A/B/33, A/B/42, A/F/15, A/F/36, D/B/13, D/B/15, D/F/19, U/F/47	----	----	A/B/7, A/B/40, A/F/8, A/F/10, D/B/5, D/B/10, D/B/16, D/F/9, U/B/1, U/B/46, U/F/6,	A/B/31, A/F/38,
IVHD Valtrate	A/B/33, A/B/40, A/F/15, D/B/16, U/B/46, U/B/1,	A/B/7, A/F/8,	---	A/B/31, A/F/10, A/F/36, A/F/38, D/B/5, D/B/10, D/B/13, D/B/15, D/F/9, D/F/19, U/F/6, U/F/47	A/B/42,

Table 4. AMMI anova for the various valepotriates of *Valeriana* chemotypes

Source	Df	Valtrate			Acevaltrate		
		SS	MSS	%TV	SS	MSS	%TV
Environment (E)	3	4.062	1.354*	11.99	0.08248	0.02749*	7.94
Chemotype (C)	20	11.420	0.571*	33.70	0.59488	0.02974*	57.25
CXE	60	18.180	0.303*	53.65	0.35381	0.00590*	34.05
PC1	22	12.450	0.566*	68.48	0.23600	0.01073*	66.60
PC2	20	4.400	0.220*	24.20	0.08600	0.00430*	24.40
PC3	18	1.330	0.074*	7.32	0.03200	0.00178*	9.00
Pooled error	168	0.227	0.001		0.00793	0.00005	
Source	df		Didrovaltrate			IVHD Valtrate	
Environment (E)	3	3.5651	1.1884*	22.30	4.902	1.634*	19.82
Chemotype (C)	20	8.7380	0.4369*	54.65	11.052	0.553*	44.69
CXE	60	3.6311	0.0605*	22.71	8.523	0.142*	34.46
PC1	22	2.1500	0.0977*	59.20	7.248	0.329*	85
PC2	20	1.2500	0.0625*	34.40	0.877	0.044*	10.3
PC3	18	0.2300	0.0128*	6.40	0.399	0.022*	4.7
Pooled error	168	0.0549	0.0003		0.256	0.002	

*= Significant at 0.001 probability significance level

valtrate had above-average predicted mean values. D/B/15 followed by A/F/36; A/B/31 followed by A/B/7had the highest predicted mean values for Didrovaltrate and IVHD valtrate, respectively.

BLUP (Best Linear Unbiased Predictor) is more advantageous to plant breeders in a mixed model approach because it results in more accurate predictions of chemotypes future mean values. It predicts random effects more accurately and works better with unbalanced or incomplete data (Smith et al. 2005). A Linear Mixed Model analysis of variance revealed significant differences between chemotypes and their interactions with an environment, similar to AMMI anova. Except for acevaltrate, the per cent of chemotypic variation was greater than the per cent of environmental variation in phenotypic variation. Albeit the contribution of the environment is less for other valepotriates, it was having a significant effect on the phenotypic expression of valepotriates. Low R^2_{CEI} of acevaltrate and didrovaltrate and moderate R^2_{CEI} of Valtrate and IVHD Valtrate demonstrated the presence of high residual variation in C X E interaction component contrasting to AMMI anova, which explained high proportion of C X E interaction through first two IPCAs.

The genotypic accuracy of selection (As), also known as model predictive accuracy, is the correlation between observed and predicted values (Olivoto et al 2019a). Moderate to very high A_s values for all the traits indicated the reliability of the model in the selection of superior genotypes. The high genotypic correlation among environments (r_{ce}) valtrate and IVHD valtrate suggested the similar trend across all the environments and easy identification of stable and superior genotypes while the low r_{ce} for Didrovaltrate and IVHD valtrate indicated difficulties in the selection of superior stable chemotypes for these valepotriates and need for detailed accurate information for selecting stable superior chemotypes.

Multi trait stability index (MTSI): MTSI was calculated based on all the valepotriates viz., valtrate, acevaltrate,

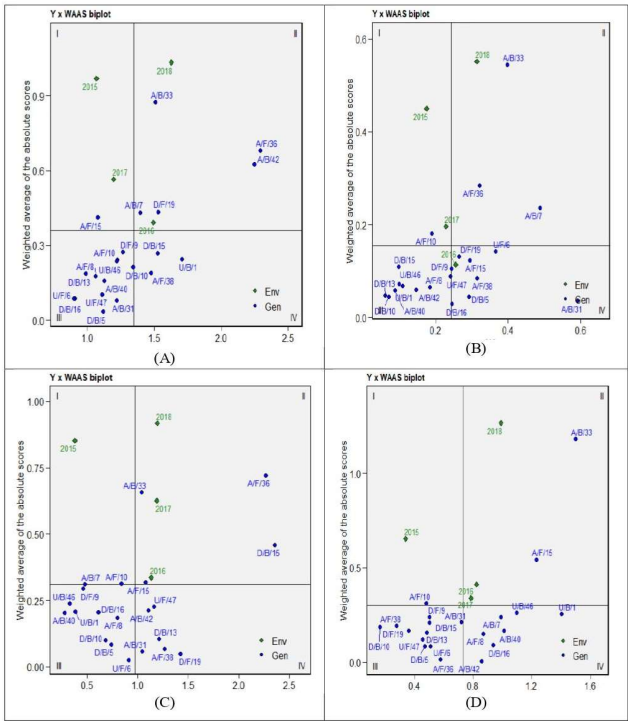

Fig. 1. Mean vs. WAAS biplot from AMMI anova for (A) Valtrate, (B) Acevaltrate, (c) Didrovaltrate, (D) IVHD valtrate

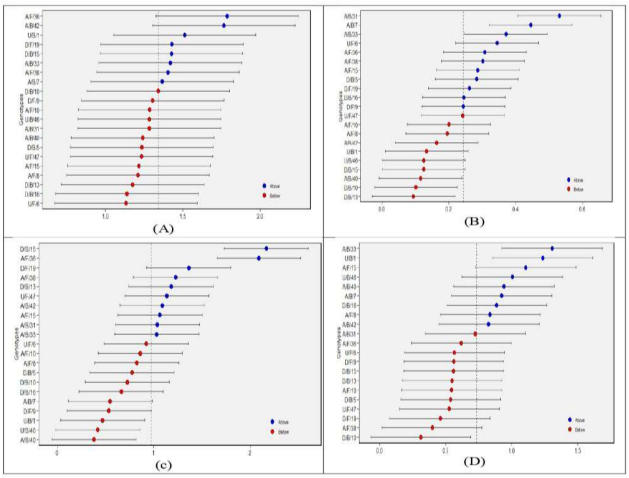

Fig. 2. BLUP mean values of Chemotypes for (A) Valtrate, (B) Acevaltrate, (c) Didrovaltrate, (D) IVHD valtrate

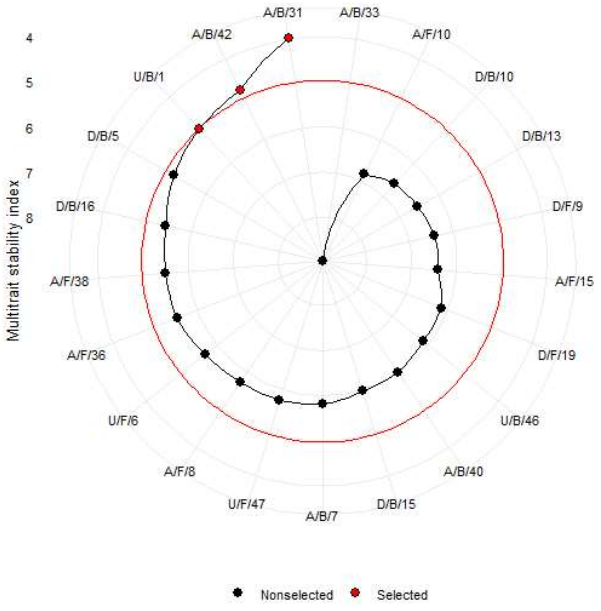

Fig. 3. MTSI values of the chemotypes

Table 5. Estimation of variance components from LMM

	Valtrate	Acevaltrate	Didrovaltrate	IVHD Valtrate
CHEM	0.066**	0.016**	0.261**	0.103**
CHEM: ENV	0.283**	0.008**	0.099**	0.121**
Error	0.055	0.018	0.207	0.064
% CV in PV	16.30	38.09	46.03	35.89
% IV in PV	69.88	19.05	17.46	42.16
% EV in PV	13.82	42.86	36.51	21.95
PV	0.405	0.042	0.567	0.287
R^2_{CEI}	0.700	0.188	0.175	0.420
A_s	0.684	0.908	0.928	0.862
r_{ce}	0.837	0.305	0.324	0.653

CV = chemotypic variation; IV = Interaction variance; PV = Phenotypic variation; EV = Environment variation ; R^2_{CEI} = co-efficient of determination of CE interaction; A_s = Accuracy of selection; r_{ce}=chemotypic correlation across environments; **=significant at 1%level based on likelihood ratio test

Table 6. Communalities and selection differential of various characters based on MTSI

VAR	FAI	Communality	Uniqueness	X_0	X_s	SD	SD (%)
Valtrate	-0.795	0.653	0.347	1.34	1.72	0.381	28.3
Acevaltrate	-0.742	0.550	0.450	0.244	0.283	0.039	16.0
Didrovaltrate	-0.696	0.851	0.149	0.976	0.847	-0.129	-13.2
IVHD valtrate	-0.155	0.922	0.0785	0.735	0.996	0.260	35.4

didrovaltrate and IVHD valtrate. A Varimax rotation criterion was applied for calculating the final loadings. The first two factors having eigenvalue more than 1.00 i.e. PC1 representing 43.5% and 30.9% variation was selected (Table 6). After Varimax rotation, the communality was ranged from 0.550 for acevaltrate to 0.922 for IVHD valtrate with a mean value of 0.743. Figure 6 shows the MTSI values of the chemotypes. The chemotypes indicated in red colour dots were selected based on their MTSI values at a selection intensity of 15 %. The stable and selected chemotypes in the order were A/B/31 followed by A/B/42, U/B/1. A selection differential of 28.3, 16.0, -13.2 and 35.4% for valtrate, acevaltrate, didrovaltrate and IVHD valtrate was observed respectively by the selection of these three chemotypes.

The lower values of MTSI indicate stable genotypes based on multiple traits. The stable and selected genotypes in the order were A/B/31 followed by A/B/42, U/B/1. It was supported by Table 4 as these were the genotypes classified as stable or fairly stable for all the traits. Besides, among these three, A/B/31 had the highest predicted mean (BLUP) for Acevaltrate, A/B/42, U/B/1 had second highest predicted mean (BLUP) for valtrate and IVHD valtrate, respectively. Therefore, the selection of these chemotypes was justified. The selection of these chemotypes would greatly benefit the improvement in mean performance as reflected by the high per cent of selection differentials.

CONCLUSIONS

A multi-year study for four years for twenty one chemotypes of *Valeriana jatamansi* using various multivariate analyses like Eberhart and Russell, AMMI, WAAS, BLUP and MTSI evaluation inculcate the stable and superior chemotypes identified through individual analysis and were combined, which identified a total of four superior and highly stable chemotypes for valtrate i.e., A/F/38, D/B/10, D/B/15, U/B/1. Similarly, A/B/31, D/B/5, A/F/38, A/F/15, D/B/16, D/F/19 in total six chemotypes are identified as superior and highly stable chemotypes for acevaltrate. For didrovaltrate A/B/31, A/F/38, D/F/19, D/B/13, these four chemotypes are identified as superior and highly stable chemotypes. Seven chemotypes namely A/B/7, A/F/8, A/B/40, U/B/46, U/B/1, D/B/16 and A/B/42 are superior and highly stable chemotypes for IVHD valtrate. BLUP identified eight above valtrate yielding chemotypes and eleven above acevaltrate yielding chemotypes. Similarly, ten chemotypes are identified as above didrovaltrate and eleven above IVHD valtrate Yielding chemotypes. Multi-trait stability index analysis identified three chemotypes (A/B/31, A/B/42 and U/B/1) as superior and stable for all the valepotriates. The selected chemotypes can be utilized for *V. jatamansi* varietal development programme and could be recommended for commercial cultivation. The multivariate techniques used in the present study proved to be very efficient to discover

superior and stable genotypes while MTSI is the new technique for evaluating stability based on multiple traits for wider adaptations.

REFERENCES

Bhatt ID, Dauthal P, Rawat S, Gaira KS, Jugran A, Rawal RS and Dhar U 2012. Characterization of essential oil composition, phenolic content, and antioxidant properties in wild and planted individuals of *Valeriana jatamansi* Jones. *Scientia Horticulturae* **136**: 61-68.

Dempster AP, Laird NM and Rubin DB 1977. Maximum likelihood from incomplete data via the EM algorithm. *Journal of Royal Statistical Society Series B* **39**: 1-38.

Eberhart SA and Russell WA 1966. Stability parameters for comparing varieties. *Crop Science* **6**: 36-40.

Jain BT, Sarial AK and Kamboj NK 2017. AMMI biplot and regression analysis for grain yield of basmati rice genotypes in different production systems. *Indian Journal of Ecology* **44**: 797-803.

Jugran AK, Bhatt ID, Rawal RS, Nandi SK and Pande V 2013. Patterns of morphological and genetic diversity of *Valeriana jatamansi* Jones in different habitats and altitudinal range of West Himalaya, India. flora-morphology, distribution, *Functional Ecology of Plants* **208**:13-21.

Jugran AK, Rawat S, Bhatt ID and Rawal RS 2019. *Valeriana jatamansi*: An herbaceous plant with multiple medicinal uses. *Phytotherapy Research* **33**: 482-503.

Mathela CS and Dev V 2003. Chemical variation among natural and commercial valerian (*Valeriana wallichii* DC) samples. *Indian Perfumer* **47**: 25-27.

Olivoto T 2019. Metan: Multi Environment Trials Analysis. R Package Version 1.1.0. https://github.com/TiagoOlivoto/metan.

Olivoto T, Lúcio AC, Silva da, Marchioro VS, Souza, VQ and Jost E 2019a. Mean performance and stability in multi-environment trials I: Combining features of AMMI and BLUP techniques. *Agronomy Journal* **111**: 1-12.

Olivoto T, Lúcio AC, Silva da, Sari BG and Diel MI 2019b. Mean performance and stability in multi-environment trials II: Selection based on multiple traits. *Agronomy Journal* **111**: 2961-2969.

Raina AP and Negi KS 2015. Essential oil composition of *Valeriana jatamansi* Jones from Himalayan regions of India. *Indian Journal of Pharmaceutical Sciences* **77**(2): 218.

Rivera JO, Loya AM and Ceballos R 2013. Use of herbal medicines and implications for conventional drug therapy medical sciences. *Alternative and Integrative Medicine* **2**(6): 1-6.

Sati S, Chanotiya CS and Mathela CS 2005. Comparative investigations on the leaf and root oils of *Valeriana wallichii* DC from North-Western Himalaya. *Journal of Essential Oil Research* **17**: 408-409.

Smith AB, Cullis BR and Thompson R 2005. The analysis of crop cultivar breeding and evaluation trials: An overview of current mixed model approaches. *Journal of Agricultural Science* **143:** 449-462.

Zobel RW, Wright MJ and Gauch Jr HG 1988. Statistical analysis of a yield trial. *Agronomy Journal* **80**: 388-393.

Received 12 March, 2023; Accepted 30 July, 2023