

Research Article

Agronomic Performance, Variance Components, and Clustering in *Vernonia galamensis* Germplasm from Ethiopia

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This study was conducted to assess the agronomic performance, variance components, and clustering analysis of 80 accessions of *Vernonia galamensis*, in alpha-lattice design with two replications at Melka Werer and Wondo Genet agricultural research centers in 2018/19. The one-way ANOVA showed that the high significant variation ($p < 0.05$) for most of the quantitative traits among accessions except for days to emergence, and the mean performance of seed yield per hectare ranged from 348.9 to 624.3 kg ha⁻¹, with an average of 474.4 kg ha⁻¹. The result of principal component analysis indicated that those exhibited more than one eigenvalue were about 71.0% of variability. While the cluster analysis based on 80% of similarity into eight clusters from the eighty accessions, the first cluster had the largest number of accessions. Overall, the study confirmed that the agromorphological characters such as the number of heads per plant, number of seeds per head, seed yield per plant, and seed weight per plot were the main contributors for seed yield per hectare in *V. galamensis*.

1. Introduction

Vernonia plant (*Vernonia galamensis* (Cass.) Less.; $2n = 18$), Asteraceae family [1–3], contains more than 500 species. It has two major centers of origin, South America and tropical Africa [4]. The greatest diversity of *V. galamensis* is found in East Africa, mainly in Ethiopia and Kenya [5]. Economically, it is used as a potential industrial crop due to a high sources of natural epoxidized oil (vernolic acid) [6] and other essential fatty acids such as linoleic acid, oleic acid, palmitic acid, stearic acid, and a trace amount of arachidic acid [7] rich in epoxidized fatty acid. It has a wide range uses in the production of oleochemicals such as paints, plastic formulations, and protective coatings [8].

Agronomic and morphological traits-based systems are the most common and easily observable markers, usually farmers and breeders use for classification and evaluation of

yield or yield related traits. Furthermore, it provides good opportunity for effective selection and conservation measures [9]. In addition, there is a need to characterize the diverse genetic resources using different statistical tools and utilize them in the breeding programmes [10]. The process usually demands partitioning the overall variability of genotypes into its heritable and nonheritable components with the use of suitable genetic parameters such as genetic coefficient of variation, heritability, genetic advance, and multivariate analysis [11].

Production of *V. galamensis* may help as a source of raw material for agroprocessing industries and for its breeding researches. As a potential industrial plant, limited information is available and this plant considered only as a wild weed colonizing disturbed areas and bare agricultural lands [2]. Since, it is underutilized, and no much attention has been given to research and conservation of this plant. The

species is also under threat of continued genetic erosion. Therefore, this study is so important including more accessions and testing at multiple locations to clearly understand the extents of the existing genetic variability for cultivation, proper conservation, and breeding programmes by using agronomic performance, variance components, and clustering analysis in *V. galamensis*.

2. Materials and Methods

2.1. Description of the Study Area. Eighty accessions of *V. galamensis*, which were collected from different regions in Ethiopia, were used as material in this study for agromorphological characterization. The field experiments were conducted at Melka Werer and Wondo Genet agricultural research centers from June to December, 2018.

2.2. Experimental Layout. The research was arranged in alpha-lattice design (8×10) with two replications. Each plot consisted of two rows of 2.5 m length with interspacing of 0.6 m and intraspacing of 0.6 m, and the interblock spacing of 1.5 m. Other cultural practices like cultivation and weeding control were done whenever needed. Five individual plants in the middle rows were tagged in each plot to avoid bordering effect and monitored until maturity. Agronomic characters such as days to emergence, days to 50% heading, days to 50% flowering, days to 90% maturity, plant height, branch number, branch length, number of heads per plant, number of seeds per head, seed yield per plant, 1000-seed weight, seed weight per plot, and seed yield per hectare were evaluated.

2.3. Data Analysis. The analysis of variance (one-way ANOVA) was computed using the GraphPad Prism version 7.0 (GraphPad Software, Inc. California, San Diego) and SAS software. Principal component analysis and cluster analysis were performed using the MINITAB® version 17.1 (Minitab, 2013) software.

3. Results

3.1. Analysis of Variance and Mean Performance of Germplasm. The results of the analysis of variance (ANOVA) for all characteristics are shown in Table 1. The mean square revealed highly significant variation ($p < 0.05$) for most of the quantitative traits of accessions, except days to emergence. The accession by location interaction was also highly significant for all characteristics except days to emergence and thousand seed weight (Table 1). The performance of the agronomic traits in eighty *V. galamensis* accessions is presented in Table 2. The mean performance of seed yield ranged from 348.9 kg ha^{-1} to 624.3 kg ha^{-1} with an average of 474.4 kg ha^{-1} . The maximum length of 50% flowering was observed at 93.5 days at Melka Werer Agricultural Research Center (MWARC) and 111.5 days at Wondo Genet Agricultural Research Center (WGARC). Moreover, the earliest 50% heading was observed at 63.5 days, and the latest 50% heading was 73.0 days at MWARC

whereas the earliest 50% heading was at 81.5 days, and the latest 50% heading was at 91.0 days at WGARC (Table 2).

3.2. Genetic Variability, Heritability, and Genetic Advance. Phenotypic, genotypic, and environmental variances were calculated for *V. galamensis* accessions (Table 3). The phenotypic coefficient of variation ranged from 11.5% (TSW) to 99.6% (BL), and the genotypic coefficient of variation ranged from 8.2% (TSW) to 95.4% (SWP). In the study, the heritability of the different traits were measured and ranged from 11.7 to 95.2% (Table 3). Moreover, the genetic advance as a percentage of mean ranged from 2.3% to 70.1%, for days to 90% maturity and seed weight per plot, respectively. Relatively high heritability coupled with high genetic advance in percentage of the mean was recorded for a number of heads per plant and seed weight per plot (Table 3).

3.3. Principal Component Analysis. Principal component analysis (PCA) indicated that the first vectors were more important than the second and other vectors. In the principal component analysis, four principal components exhibited more than one eigenvalue and showed 71.0% of the variation (Table 4). The first PC accounted for 37.8% of the total variation, whereas the corresponding values for the second to the fourth PCs were 15.3%, 9.6%, and 8.4%, respectively. Traits such as days to 50% heading, days to 90% maturity, number of heads per plant, number of seeds per head, seed yield per hectare, and 1000-seed weight were indicated the major contributors for the variations in the first principal component (Table 4).

3.4. Cluster Analysis. The cluster analysis is based on 80% similarity of eighty accessions into eight clusters (Figure 1, Table 5). Cluster I had the largest number of accessions and characterized by relatively high seed yield per plant, seed weight per plot, and seed yield per hectare. Accessions in cluster II ($n = 15$) had the highest thousand seed weight. Cluster III had the sixteen accessions, characterized by the highest number of seeds per head. Cluster-IV ($n = 6$) is characterized by the highest number of branches. Cluster V ($n = 3$ accessions) was mainly distinguished by having the lowest value in thousand seed weight. Cluster VI had five accessions, characterized by the highest number of heads per plant and number of seeds per head. Cluster VII was comprised of twelve accessions and characterized with the highest number of days to 50% heading, plant height, days to 50% flowering, and thousand seed weight. Cluster VIII contained only two accessions and characterized by the highest branch length.

4. Discussion

Genetic diversity analysis of germplasm using agromorphological traits is an initial step for crop improvement. In line with this, 80 correctly stated *V. galamensis* were used for the agromorphological traits. The mean square showed

TABLE 1: Mean squares for 13 quantitative traits of 80 *Vernonia galamensis* accessions evaluated at Melka Werer and Wondo Genet agricultural research centers.

Source of variation	Mean square and significant tests																
	DF	DE	DFH	PH	DFH	PH	DFH	NB	BL	DNM	DF	NHP	SPH	SYP	TSW	SWP	SYH
Accession	79	1.53	7.44	352.297**	8.76*	154.18	86.07*	152.49	86.07*	152.49	79	536.14*	312.05	11.34*	0.075	1117.34*	12944.2*
Location	1	0.03	20704.61*	434992.26*	14137.90*	943.77	16.707*	20464.00*	16.707*	20464.00*	1	395606.26*	133501.89*	4130.73*	0.48*	24888.971*	2496910.68*
Block (rep)	7	1.25	10.86**	702.406**	2.16	214.02	20.22	90.189	20.22	90.189	7	396.66*	194.96	10.8	0.06	2254.77	17208.1
Rep	1	1.25	42.05	6200.481*	21.53*	520.84	12.21**	20464.00*	12.21**	20464.00*	1	854.78	599.68*	5.77	0.31*	8439.06*	67753.82*
Accession* location	79	0.74	9.57**	391.120**	11.90*	52.16**	86.14**	33.93**	86.14**	33.93**	79	1310.478*	357.46*	13.90*	0.07	2269.08*	20889.64*
Error	152	0.83	5.84	221.309	1.08	86.25	38.30*	154.92	38.30*	154.92	152	146.5389	197.69	3.72	0.04	41.58	20.42
CV (%)		8.51	3.17	9.49	1.076	26.44	11.05	7.25	11.05	7.25		7.87	9.87	12.33	6.53	29.36	30.16

*Significant at $p < 0.05$. DF, degree of freedom; DE, days to emergence; DFH, days to 50% heading; PH, plant height; DFF, days to 50% flowering; NB, number of branches; BL, branch length; DNM, days to 90% maturity; NHP, heads per plant; SPH, heads per plant; SYP, seed yield per plot; SWP, seed weight per plot; SYH, seed yield per hectare.

TABLE 2: Estimates of mean performance and ranges for 13 quantitative traits of *Vernonia galamensis* grown at Melka Werer and Wondo Genet agricultural research centers.

Quantitative traits	Mean performance					
	Melka Werer			Wondo genet		
	Mean	Minimum	Maximum	Mean	Minimum	Maximum
Days to emergence	10.74 ± 0.1	9.0	12.5	10.72 ± 0.1	9.5	13.0
Days to 50% heading	68.13 ± 0.3	63.5	73.0	84.22 ± 0.3	81.5	91.0
Days to 50% flowering	89.82 ± 1.3	85.0	93.5	103.11 ± 1.7	96.0	111.5
Plant height (cm)	119.88 ± 0.3	89.5	143.5	193.62 ± 0.4	159.5	228.0
Number of branches/plant	33.41 ± 0.9	17.8	52.4	36.85 ± 0.9	19.5	59.5
Branch length (cm)	56.26 ± 0.8	46.0	71.9	72.81 ± 0.8	43.0	76.0
Days to 90% maturity	163.65 ± 0.9	151.0	177.0	179.64 ± 0.8	165.5	198.5
Number of head/plant	118.73 ± 2.9	84.9	188.4	189.06 ± 2.2	132.4	239.2
Number of seed/head	121.99 ± 1.8	93.1	163.5	162.84 ± 1.2	141.2	189.0
Seed yield/plant (g)	12.04 ± 0.2	8.7	16.8	19.22 ± 0.3	14.9	25.7
Seed weight/plot (g)	113.74 ± 39.5	58.6	246.8	169.51 ± 44.3	116.8	331.2
1000-seed weight (g)	3.00.00 ± 0.0	2.7	3.4	3.08 ± 0.0	2.4	3.5
Seed yield (kg ha ⁻¹)	385.49 ± 9.4	246.8	822.7	562.16 ± 11.5	406.0	1104.0

Significant at $p < 0.05$.

TABLE 3: Estimates of mean, genotypic coefficient of variations (GCVs), phenotypic coefficient of variations (PCVs), heritability, and genetic advance as a percentage of the mean (GA%) for 13 quantitative traits.

Quantitative traits	Mean	Vp	Vg	Ve	PCV%	GCV%	ECV%	h ² B	GA	GAM
DE	10.7	0.8	0.4	0.4	28.0	19.8	3.9	50.3	1.1	9.8
DFH	76.2	5.7	2.8	2.9	27.3	19.0	3.8	48.6	8.6	11.3
DFP	96.5	10.5	10.0	0.6	33.1	32.2	1.6	94.8	14.3	14.8
PH	156.8	90.3	69.9	20.4	75.9	66.8	13.0	77.4	65.6	41.9
NB	35.1	12.3	8.1	4.2	59.2	48.0	12.1	65.6	15.1	42.9
BL	64.5	55.5	36.3	17.1	99.5	80.5	26.5	65.4	11.1	19.8
DNM	171.7	87.7	10.3	77.5	71.5	24.4	45.1	11.7	3.9	2.3
NHP	153.9	108.1	94.8	13.3	83.8	78.5	8.6	87.7	78.1	50.7
SPH	142.4	106.0	57.2	98.9	86.3	63.3	64.4	53.9	29.5	20.7
SWP	141.6	135.5	129.0	106.5	97.8	95.4	75.2	95.2	99.3	70.1
SYP	15.6	5.8	3.9	1.9	60.7	49.9	11.9	67.7	6.4	41.2
SYH	473.8	313.4	227.2	86.2	81.3	69.2	18.2	72.5	95.9	20.2
TSW	3.0	0.0	0.0	0.0	11.5	8.1	2.7	50.0	0.3	8.3

DE, days to emergence; DFH, days to 50% heading; PH, plant height; DFP, days to 50% flowering; NB, number of branches; BL, branch length; DNM, days to 90% maturity; NHP, number of heads per plant; SPH, number of seeds per head; SYP, seed yield per plant; SWP, seed weight per plot; SYH, seed yield per hectare; TSW, 1000-seed weight; Vg, genotypic variation; Vp, phenotypic variation; Ve, environmental variation; GCV, genotypic coefficient of variation; PCV, phenotypic coefficient of variation; GA, genetic advance; GAM, genetic advance as percentage of mean at 5% selection intensity.

TABLE 4: Principal component analysis for 13 quantitative traits of 80 *Vernonia galamensis* accessions.

Variables	PC1	PC2	PC3	PC4
Days to emergence	0.03	-0.11	0.60	0.33
Days to 50% heading	0.93	-0.18	-0.10	0.04
Plant height (cm)	0.90	-0.07	-0.06	0.12
Days to 50% flowering	0.90	-0.18	-0.11	0.08
Number of branches/plant	0.24	-0.22	0.56	-0.33
Branch length (cm)	-0.02	0.45	0.17	0.73
Days to 90% maturity	0.61	-0.34	0.27	-0.15
Number of head/plant	0.82	-0.08	-0.05	0.11
Number of seed/head	0.80	-0.02	-0.23	0.12
Seed yield/plant (g)	0.79	-0.14	-0.16	0.16
Seed weight/plot (g)	0.70	0.61	0.14	-0.27
Seed yield (kg ha ⁻¹)	0.69	0.63	0.13	-0.27
1000-seed weight (g)	0.21	-0.08	0.45	0.11
Eigenvalue	5.86	1.25	1.11	1.01
Proportion	0.38	0.15	0.10	0.08
Cumulative	0.38	0.53	0.63	0.71

highly significant variation for most of the quantitative traits such as the number of heads per plant, number of seeds per head, and seed yield. These variations among accessions would provide a good opportunity for improvement through the selection of the cultivated plant. This finding is consistent with the previous report Baye et al. [5] and Shimelis et al. [12].

The mean performance showed significant differences among seed yield and yield components. For example, five quantitative traits including number of heads per plant, number of seeds per head, seed yield per plant, seed weight per plot, and seed yield per hectare showed three times more performances compared to minimum mean performance range. Such significant and wide range of genetic variation indicates that the existence of large genetic variability among the tested accessions and extrapolation to the crop as a whole could be used as a fundamental information for further work in cultivation, conservation, and breeding. Baye et al. [5],

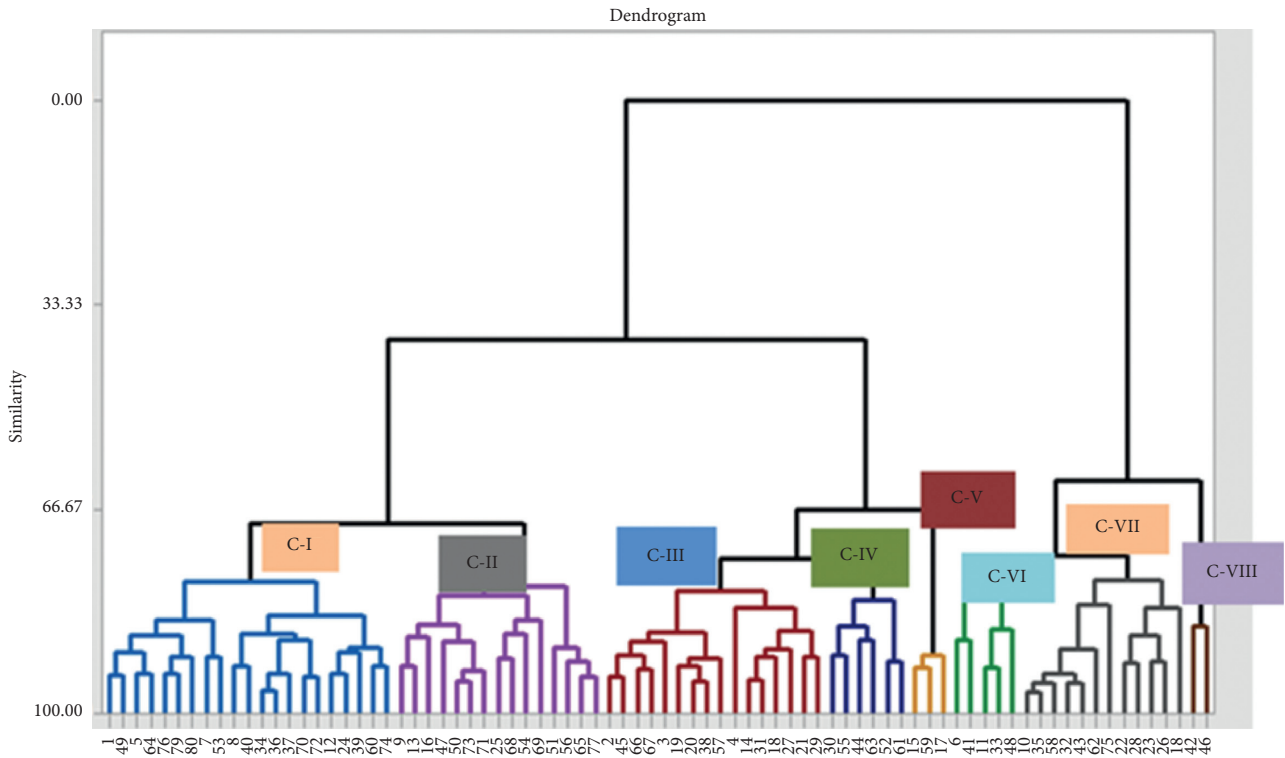


FIGURE 1: Dendrogram from cluster analysis of eighty accessions of *Vernonia galamensis*.

TABLE 5: Mean values of 13 quantitative traits used in the clusters of 80 *Vernonia galamensis* accessions.

	Cluster							
	I	II	III	IV	V	VI	VII	VIII
DE	10.25	10.94	10.41	10.67	10.84	10.38	11.17	10.79
DFH	75.50	76.17	75.72	76.08	76.17	76.13	77.92	76.44
PH	158.47	157.78	152.48	159.79	157.55	158.00	161.52	156.68
DFE	81.41	81.63	79.53	82.18	81.52	81.50	83.53	81.30
NB	36.75	32.55	29.12	41.68	36.34	36.09	32.20	39.62
BL	54.19	56.65	55.52	55.23	54.70	56.66	54.27	57.94
DNM	172.00	173.08	169.52	176.46	170.23	165.13	174.25	172.15
NHP	154.67	143.73	149.21	173.00	153.26	176.08	143.83	160.37
SPH	139.59	141.48	145.28	133.09	140.82	153.79	138.23	145.13
SYP	16.26	15.15	15.76	15.72	15.49	16.01	15.03	15.99
SWP	173.99	160.45	123.29	124.49	137.72	158.36	107.69	148.77
SYH	607.75	533.10	411.89	396.14	462.10	560.32	358.99	499.70
TSW	3.03	3.05	3.03	3.01	2.89	2.98	3.11	3.04

DE, days to emergence; DFH, days to 50% heading; PH, plant height; DFE, days to 50% flowering; NB, number of branches; BL, branch length; DNM, days to 90% maturity; NHP, heads per plant; SPH, seeds per head; SYP, seed yield per plant; SWP, seed weight per plot; SYH, seed yield per hectare; TSW, 1000-seed weight.

Shimelis et al. [12], and Mebrahtu et al. [13] reported a similar results with slight differences in the magnitude which could be attributed to differences in the number of samples studied and experimental sites used. In addition, the average seed yield per hectare ($473.82 \pm 20.42 \text{ kg ha}^{-1}$) was comparable with the result of Mebrahtu et al. [13] and slightly lower than with the results of Baye et al. [2] and Shimelis et al. [12].

Phenotypic coefficient of variation (PCV) was observed higher than their corresponding genotypic coefficient of variation (GCV) for all the characters and had environmental effects on all the traits. According to Jakhar et al. [14] and Bhargav et al. [15], the PCV and GCV values greater

than 20% are considered as high, values between 10 and 20% are considered as medium, and less than 10% are classified as low. Therefore, according to the classification, high PCV and GCV values were recorded for number of branches, days to 90% maturity, number of heads per plant, number of seeds per head, and seed yield per hectare, suggest the possibility of improving these traits through selection. On the other hand, it is estimated that GCV and PCV were low in the study for thousand seed weight (11.51% and 8.14%, respectively). Baye et al. [16] reported that the phenotypic and genotypic variation were closer to each other for most of the characters; however, the magnitude of the environmental variation was

relatively lower than the genotypic variation for most characters except days to 90% maturity and number of seeds per head.

In the study, the heritability of the different traits ranged from 11.69 to 95.22%. High heritability does not always indicate a high genetic gain; however, heritability with genetic advance as a percentage of mean should be considered in predicting the ultimate effect of selecting superior varieties. The genetic advance as a percentage of mean ranged from 2.3 to 70.13% for days to maturity, and seed weight per plot, respectively. Relatively high heritability coupled with high genetic advance as percentage of the mean was recorded for a number of heads per plant and seed weight per plot, indicating that selection for the stated characters could be more effective due to additive gene action. Johnson et al. [17] reported that high heritability coupled with high GAM is usually more helpful in predicting gain under selection than heritability alone. Rosielle and Hamblin [18] reported that heritability and genetic advance values may be concealed due to a greater genotype by environment under unfavorable condition. Ceccarelli [19] on the contrary reported that there is no interrelationship between the type of the environment and the magnitude of heritability and genetic advance values.

Principal component analysis (PCA) indicated that four principal components exhibited more than one eigenvalue and showed 71.0% of the variation. The eigenvalues above 1 indicate the evaluated principle component weight values are reliable. Traits such as days to 50% heading, days to 90% maturity, number of heads per plant, number of seeds per head, seed yield per hectare, and 1000-seed weight were the major contributors for the variations observed in the first principal component. Similar observations were found by researchers [20–24].

Clustering was done based on the mean values of the agromorphological traits, and 65% of the accessions were grouped under the first three clusters, indicating the existence of considerable differences in the mean values of different traits. Accessions falling under clusters 1, 2, 3, and 7 had a maximum mean performance in traits such as seed yield per plant, seed yield per hectare, number of seeds per head, and number of heads per plant. Moreover, the mean based clustering pattern indicates a wide diversity of accessions between different groups and their close relationship within a cluster. It is, therefore, logical to expect a higher genetic diversity from accessions of different clusters than within a cluster, which is also important in breeding and parental selection [25].

5. Conclusion

The study revealed that there were significant genetic variabilities for all the quantitative traits ($p < 0.05$), except days to emergence among *V. galamensis* accessions. Seed yield was positively and significantly associated with the number of heads per plant, number of seeds per head, and seed yield per plant, indicating the importance of these traits for seed yield improvement studies. The magnitude of phenotypic coefficient of variation was higher than their corresponding

genotypic coefficient of variation for all the characters, suggesting the presence of environmental influence on all the traits studied. Relatively high heritability coupled with high genetic advance as percentage of the mean was recorded for the number of heads per plant and seed weight per plot, indicating that selection for these characters could be more effective. In addition, four principal components with 71.0% of the variation and eight clusters were observed. Generally, the study revealed that the existence of variabilities in *Vernonia galamensis* plant. Most of the values of variability detected are important as fundamental information for future *V. galamensis* cultivation, breeding, and conservation in Ethiopia. In addition, breeding studies of this plant should be supported by advanced genetic engineering technology.

Data Availability

The dataset that supports the findings in the study is available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

AM and KT designed the study. In addition, KT supported the field work, and AM performed the statistical data analysis and wrote the manuscript. All the authors read and approved the final manuscript.

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