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STABILITY ASSESSMENT FOR RHIZOME YIELD AND ITS CONSTITUENT CHARACTERISTICS IN VARIOUS GENOTYPES OF TURMERIC

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Key words: Turmeric, Stability, Sustainability index, Rhizome yield

Abstract

Turmeric is an important rhizomatous spice as well as medicinal plant with the wide genetic variability with regard to growth and yield that thrives well at lower altitudes to higher elevations up to 1600 m above MSL and also under rainfed conditions. Stability analysis was done in 55 turmeric genotypes, including three check varieties, during 2016-17 and 2020-21 at Tamil Nadu Agricultural University, Coimbatore, with *per se* performance. The joint regression analysis revealed no significant difference among various genotypes, indicating the uniformity of the genotypes. However, the G x E (linear) interaction was significant for three out of five traits studied, revealing the profound influence of environment on phenotypes. Based on individual parameter's of stability (xi bi and S2 di), genotypes CL 2 and CL 100 were found stable in performance over the years. Further 32 genotypes were found to have significantly higher regression coefficients along with mean values above the general mean for fresh rhizome yield, depicting the scope for improved performance under favourable farming conditions. Based on the mean performance, regression coefficient, and deviation from regression values, it was found that the stability of yield was imparted in the genotypes, *viz*., CL 100, CL 122, CL 147, CL 213, and CL 269, through the stable performance of major yield- contributing traits like number of leaves per plant, number of tillers per plant, and rhizome yield per plant. These genotypes may be useful genetic resources for the development of high- yielding, stable varieties of turmeric.

Introduction

Turmeric (*Curcuma longa* L.), is a member of the Zingiberaceae family. This plant holds significant economic value as it serves as a vital spice and medicinal herb for the production of curcumin, oleoresin, and essential oil. These valuable components find applications in the pharmaceutical and cosmetics industries. Originally native to South East Asia, turmeric has spread its cultivation to countries such as India, Bangladesh, Sri Lanka, and Indonesia. Despite India's prominent position as a leading turmeric producer and the existence of a few high-yielding cultivars, the overall productivity and quality of this crop remain unsatisfactory. This is due to the differential response of genotypes under varying environments (Sanwal *et al.* 2007).

Adequate information is not available with respect to adaptability of turmeric genotypes to seasonal and environmental variations. Due to its multipurpose use, cultivation is increasing in the non-traditional areas of the country. The farmers of different states grow the landraces available with them. Since there are very few varieties and the majority of them were developed from available germplasm, the performance of turmeric germplasm at different years is of great importance in respect of screening them for their stability. The G x E interaction shows the differential response of genotypes to different environmental conditions and their consistency in performance over the years. An ideal variety should have a high mean yield combined with a low degree of fluctuations when grown over diverse environments (Arshad *et al*. 2003). Therefore, it is

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crucial to cultivate genotypes that exhibit stable and superior performance in order to optimize yield. Additionally, growing high-value crops like turmeric can greatly contribute to improving the agricultural economy of India.

Hence, the current study was aimed at evaluating the stability of turmeric genotypes for yield and yield attributes in the Coimbatore region of Tamil Nadu.

Materials and Methods

The experimental materials comprising 55 turmeric genotypes were grown during five consecutive years (from 2016-17 to 2020-21) at Tamil Nadu Agricultural University, Coimbatore. The land was ploughed thoroughly and brought to a fine tilth. At the time of last ploughing, FYM was applied at 20 t/ha. Distance between two rows was 0.45 m and 0.15 m spacing between plants in a row. The plot size of the experiment was 3 x 5 m. A fertilizer dose of 25 : 60 : 106 NPK kg/ha was uniformly applied to all the plots. Three hand weedings on 30th, 60th and 90th days after planting were given commonly for all the plots. The experiment was conducted under irrigated conditions and adopted a randomized block design with three replications. The observations were recorded on plant height (cm), number of leaves per plant, number of tillers per plant, leaf length (cm), and rhizome yield/ plant (kg). The data were analysed statistically for stability parameters based on model (Eberhart and Russel 1966). The sustainability indices (SI) were estimated as used by earlier workers (Gangwar *et al.* 2004). The sustainability index was divided into five groups, *viz.*, very low (upto 20%), low (21-40%), moderate (41-60%), high (61-80%) and very high (above 80%).

Results and Discussion

The joint regression analysis revealed highly significant differences among the genotypes as well as environments for all the traits (Table 1). Genotype x Environment (GxE) interaction was studied for rhizome yield per plant and its component characters *i.e*. plant height (cm), number of leaves per plant, number of tillers per plant and leaf length (cm). G × E interactions were highly significant for plant height and rhizome yield per plant. Similar observations were reported in turmeric (Kumar *et al*. 2004).

Table 1. Joint regression analysis of various traits of turmeric tested over five years.

Source of variation	D.F.	Mean square				
		Plant height (cm)	No. of leaves	Leaf length (cm)	No. of tillers per plant	Rhizome yield per plant (kg)
Genotype (G)	54	810.51**	1.88**	41.56**	2.44**	0.02*
Environment (E)	4	862.47**	85.13**	1099.71**	9.98**	1.00**
G x E	216	153.57*	1.40	44.67*	0.95	0.01*
E + (G x E)	230	166.45*	2.92	63.85*	1.11*	0.02*
Env. (linear)	1	3447.61**	340.50**	4398.73**	39.93**	4.00**
G x E (linear)	54	150.75**	2.98	97.06*	1.17	0.01*
Pooled deviation	165	151.71**	0.86	26.72*	0.86*	0.01*
Pooled error	550	11.25	0.14	2.41	0.02	0.00

*Significant at 5% level of significance, **Significant at 1% level of significance.

Highly significant mean squares due to environment (linear) for all the traits indicated considerable differences among the environments and their predominant effects on the traits. This was due to variation in climatic conditions during years. Highly significant pooled deviations for plant height, number of leaves per plant, number of tillers per plant, leaf length and rhizome yield per plant indicated a non-linear response of the genotypes due to environmental changes and the greater role of unpredictable components of G x E interaction towards differences in stability of the genotypes. It is reported that both predictable and unpredictable components contributed significantly towards the differences in stability of ginger genotypes (Das *et al.* 2000), coriander genotypes (Verma *et al*. 2014, Chitra 2017), fennel genotypes (Verma and Solanki 2015) and turmeric genotypes (Govind 2013). However, predictions for unpredictable traits can be made by considering the stability parameters of individual genotypes (Singh *et al.* 1991).

The linear regression analysis facilitates identification of genotypes having wider adaptability over a range of environments. The stability analysis was done following the model of Eberhart and Russel (1966), which suggested two stability parameters: (i) linear regression and (ii) deviation from such regression. According to them, a stable variety will have high mean performance, a regression coefficient (b_i) near unity, and a deviation from regression (s^2d_i) close to zero. Therefore, all the three parameters, *i.e*., mean, linear regression and non-linear responses, seem to be equally important. The stability parameters high mean, significant regression coefficient and non-significant deviation from regression for plant height showed that out of 55 genotypes, six genotypes, namely CL 2 (117.95, -2.76 and 65.63), CL 15 (113.44, -3.02 and 115.15), CL 121 (110.22, -3.43 and 174.11), CL 22 (105.72, -3.36 and 83.72), CL 114 (99.75, 1.08 and 1.70), and CL 52 (98.72, -0.07 and 41.26) recorded were found to be stable and suitable for favourable environments (Table 2). The genotypes namely CL 2, CL 121, and CL 192, possessed a higher number of leaves per plant than the population mean (8.91) and a significant regression coefficient (b_i>1), along with non-significant deviation from regression indicating their stability and suitability to favourable environments (Table 2).

Five genotypes, namely, CL 121, CL 130, CL 132, CL 189 and CL 192 recorded more number of tillers per plant than population mean (3.23), non-significant regression co-efficient, and deviation from regression and were found stable and suitable for wider environments (Table 3). For the trait leaf length, the single genotype CL 192 (41.00, 1.08, and 3.56) recorded a high mean value, a significant regression coefficient along with a non-significant deviation from regression indicating their stability and suitability to favourable environments (Table 3). For the same trait, the genotype CL 75 (39.25, 1.96, and 0.39) recorded high population mean, a non-significant regression co-efficient, and a deviation from regression and were found stable and suitable for wider environments. A high mean value over the population mean (0.430), significant regression co-efficient, and non-significant deviation from regression were recorded in the genotype CL 2 for rhizome yield per plant, indicating their stability and suitability to favourable environments (Table 4).

It was reported that the generalization regarding stability of a variety for all the descriptors is rather difficult (Singh and Singh 1980). The current studies also revealed that the genotypes exhibited variability in stability and did not demonstrate a consistent linear response across all traits. However, the overall stability may be considered on the basis of the compensation pattern of different traits. For rhizome yield per plant, the sustainability index (SI) for all the genotypes ranged from 62.33% (CL 2) to 118.27% (CL 88). The check CL 189 recorded the highest SI (98.40%) among all the checks (Table 4), indicating low fluctuations in its performance over the locations as compared to checks. Among the genotypes identified for wider adaptability, six genotypes, namely, CL 88, CL 131, CL 173, CL 174, CL 194, and CL 198, showed high SI, thus indicating that the genotypes would give better performance consistently over the diverse

Table 2. Stability parameters for plant height and number of leaves per plant in turmeric.

Genotype	Plant height (cm)				No. of leaves per plant			
	Mean	b_i	S^2d_i	Sustainability index	Mean	b_i	S^2d_i	Sustainability index
CL 2	117.95	-2.76	65.63	56.62	11.54	0.85	6.94	71.92
CL 15	113.44	-3.02	115.15	58.87	9.64	2.39	1.70	86.10
CL 22	105.72	-3.36	83.72	63.17	9.29	1.98	1.28	89.34
CL 35	89.66	2.07	34.04	74.48	8.70	1.49	0.21*	95.40
CL 41	89.67	-1.32*	-4.14*	74.47	8.96	2.05*	0.22*	92.63
CL 42	84.13	-0.80	96.94	79.38	9.16	1.93	0.65	90.61
CL 43	86.59	1.20	-5.82*	77.12	9.60	0.01	2.79	86.46
CL 49	90.21	2.21	40.65	74.03	9.28	-0.18*	0.30	89.44
CL 52	98.72	-0.07	41.26	67.65	8.36	0.63*	-0.07*	99.28
CL 74	91.01	-0.52	55.92	73.38	8.38	1.27	2.69	99.05
CL 75	92.22	-2.84	39.95	72.41	8.90	1.25	1.11	93.26
CL 78	79.10	2.97	5.13*	84.42	8.28	0.38	1.83	100.24
CL 88	73.04	3.31	19.31	91.43	9.01	0.26	0.62	92.12
CL 89	79.72	2.83	83.13	83.77	8.62	-0.24*	0.51	96.29
CL 100	82.91	3.67	25.90	80.55	9.51	0.63*	-0.08*	87.28
CL 114	99.75	1.08	1.70*	66.95	9.22	0.87	-0.10*	90.02
CL 120	89.15	-1.43	45.16	74.91	8.26	0.90	0.27	100.48
CL 121(C)	110.22	-3.43	174.11	60.59	10.25	0.68	-0.03*	80.98
CL 122	79.47	0.68	1.21*	84.03	9.04	0.60	1.46	91.81
CL 130	59.98	2.30	-1.32*	111.34	8.36	0.37	2.19	99.28
CL 131	67.91	3.42	27.68	98.34	8.60	0.45	0.63	96.51
CL 132	75.77	0.98	-5.70*	88.14	8.62	0.49	0.08*	96.29
CL 133	63.81	2.38	33.96	104.65	9.16	0.05*	0.15*	90.61
CL 134	62.02	2.62	51.40	107.67	8.62	-0.12*	0.61	96.29
CL 135	70.74	3.67	148.41	94.40	8.18	0.50	1.08	101.47
CL 144	74.68	-0.83	55.76	89.42	8.42	0.17	0.34	98.57
CL 146	86.20	2.18**	-10.04*	77.47	8.62	-0.24*	0.51	96.29
CL 147	92.55	0.72	7.03*	72.16	9.06	1.20	0.13*	91.61
CL 148	76.58	0.01	19.63	87.20	8.32	0.29*	0.06*	99.76
CL 149	79.52	-0.39	38.16	83.98	8.19	0.79	-0.05*	101.34
CL 151	70.09	1.38	-10.53*	95.28	8.13	0.58	1.73	102.09
CL 152 (C)	71.25	1.68	26.60	93.73	8.72	0.37	0.43	95.18
CL 156	90.25	1.24	-5.31*	73.99	9.07	2.07*	0.24	91.51
CL 158	80.35	2.65	66.54	83.11	9.72	1.38	0.93	85.39
CL 169	93.65	-1.74	66.77	71.31	9.01	0.97	-0.12*	92.12
CL 172	87.97	-2.59	42.16	75.91	9.00	0.63	1.01	92.22
CL 173	84.50	-0.69	59.11	79.03	8.27	1.51	0.07*	100.36
CL 174	68.93	2.04*	-8.30*	96.88	8.80	0.75	-0.09*	94.32
CL 175	71.23	0.75	-3.24*	93.75	8.39	1.39*	-0.08*	98.93
CL 184	81.81	-3.57	44.51	81.63	9.20	2.13*	0.50	90.22
CL 189 (C)	63.39	3.38	29.56	105.35	9.11	1.39	1.94	91.11
CL 192	81.53	3.06	6.21*	81.91	10.02	1.44	0.38	82.83
CL 194	77.33	1.41	-10.07*	86.36	9.32	1.91*	0.33	89.06
CL 195	75.65	2.27	41.03	88.27	9.67	1.31	0.19*	85.83
CL 198	67.71	3.77	43.37	98.63	8.58	1.27	-0.05*	96.74
CL 199	62.31	2.43	75.76	107.17	9.05	1.17	0.00*	91.71
CL 200	63.67	2.40	43.86	104.88	8.86	1.46	0.53	93.68
CL 201	66.05	2.73	79.85	101.11	8.47	1.10	-0.07*	97.99
CL 209	60.67	1.96	-7.10*	110.07	8.79	1.79	0.55	94.43
CL 213	69.07	2.59	0.61*	96.68	9.32	1.76*	0.05*	89.06
CL 255	69.03	0.96	-7.08*	96.74	8.62	0.93	1.13	96.29
CL 260	76.06	1.89**	-10.62*	87.80	8.04	0.51	0.75	103.23
CL 262	68.05	1.51*	-10.86*	98.13	8.73	1.66*	0.01*	95.07
CL 263	71.24	1.76	72.99	93.74	8.46	1.64	0.79	98.11
CL 269	84.83	4.17	46.45	78.72	8.54	2.21*	0.72	97.19
Population mean	80.35	0.97			8.91	1.00		
SE (mean)	3.45	1.34			0.47	0.38		

Table 3. Stability parameters for number of leaves per plant and leaf length in turmeric.

Genotype	No. of tillers per plant				Leaf length (cm)			
	Mean	b_i	S^2d_i	Sustainability index	Mean	b_i	S^2d_i	Sustainability index
CL 2	2.46	0.88**	-0.01	102.44	39.73	3.39	44.62	86.71
CL 15	2.45	0.81*	0.08*	102.86	39.31	3.02*	13.87	87.64
CL 22	3.04	-0.08	0.30	82.89	35.25	3.13*	9.20	97.73
CL 35	3.20	1.90*	0.42*	78.75	38.08	1.10	53.65	90.47
CL 41	2.49	-0.12*	0.36*	101.20	33.10	3.53**	11.21	104.08
CL 42	2.37	0.67	0.16	106.33	33.16	2.56*	16.33	103.89
CL 43	2.28	1.06*	-0.01	110.53	34.62	2.40	52.19	99.51
CL 49	3.04	0.77	0.00	82.89	40.34	2.60	173.54	85.40
CL 52	3.15	-0.08	0.77	80.00	39.07	2.51	37.66	88.18
CL 74	3.58	1.06	0.14	70.39	36.77	1.49	7.56	93.69
CL 75	3.58	1.33	1.03	70.39	39.25	1.96*	0.39*	87.77
CL 78	2.67	1.67	0.17*	94.38	35.64	0.79	-1.89*	96.66
CL 88	2.63	1.74	0.95	95.82	38.90	0.28*	-0.97*	88.56
CL 89	2.72	0.83	0.00*	92.65	40.00	1.04	46.41	86.13
CL 100	3.34	0.33	0.10*	75.45	42.86	0.40	6.00	80.38
CL 114	3.35	0.40	0.12*	75.22	35.52	1.39*	-1.56*	96.99
CL 120	3.70	-0.05	0.41*	68.11	39.25	1.08	32.11	87.77
CL 121(C)	5.05	-3.78*	7.93	49.90	32.96	2.34	26.62	104.52
CL 122	3.79	1.34	0.42*	66.49	35.52	0.41	21.35	96.99
CL 130	5.56	-1.11	2.58	45.32	34.80	0.48*	-0.50*	98.99
CL 131	3.23	1.51*	0.34	78.02	39.40	0.05	4.76	87.44
CL 132	4.04	0.88	0.09*	62.38	39.20	0.18	4.12	87.88
CL 133	3.48	-0.07	0.35	72.41	38.27	0.93	78.88	90.02
CL 134	3.17	0.91**	0.05*	79.50	32.96	1.04	20.04	104.52
CL 135	3.94	1.81	0.60*	63.96	37.63	0.64	38.93	91.55
CL 144	2.48	0.42*	0.20*	101.61	30.17	1.09	0.53*	114.19
CL 146	2.82	1.36	0.17*	89.36	36.69	2.31*	6.19	93.89
CL 147	3.82	1.79	0.70*	65.97	41.00	1.12	-0.40*	84.02
CL 148	2.62	1.74	4.20*	96.18	32.10	1.62	0.95*	107.32
CL 149	2.98	-0.15	0.41*	84.56	35.98	1.18	-0.60*	95.75
CL 151	3.82	1.74	1.69*	65.97	33.92	-0.39*	10.93	101.56
CL 152 (C)	3.15	2.49	1.11	80.00	38.15	0.36	14.42	90.30
CL 156	3.76	2.60	1.55*	67.02	39.30	0.76	23.73	87.66
CL 158	3.34	0.33	0.10	75.45	35.01	1.23	40.83	98.40
CL 169	3.78	1.22	1.24	66.67	38.52	1.42	62.90	89.43
CL 172	3.68	2.20*	0.64*	68.48	35.70	1.75	7.40	96.50
CL 173	3.14	1.58	0.36	80.25	39.04	0.82	99.46	88.24
CL 174	3.42	1.11	1.33*	73.68	37.08	-0.01**	-0.42*	92.91
CL 175	3.53	2.83	1.13*	71.39	35.02	0.17	30.88	98.37
CL 184	2.93	1.63	0.12*	86.01	40.80	0.66	96.88	84.44
CL 189 (C)	4.82	-3.31	5.04	52.28	37.21	0.86	1.91*	92.58
CL 192	4.59	2.70	0.75*	54.90	41.00	1.08	3.56*	84.02
CL 194	3.11	1.45	0.04*	81.03	39.73	0.96	7.88	86.71
CL 195	3.70	2.86	1.14	68.11	36.87	0.91	13.93	93.44
CL 198	2.45	1.94	0.37	102.86	31.22	0.86	-2.05*	110.35
CL 199	2.25	2.31*	0.80	112.00	37.99	-0.51*	6.14	90.68
CL 200	2.91	2.69*	1.13*	86.60	40.24	-0.70*	5.01	85.61
CL 201	2.21	1.85	0.41	114.03	39.93	-0.59*	3.76*	86.28
CL 209	2.75	1.81	0.27	91.64	36.39	-0.45	51.48	94.67
CL 213	3.07	0.06	0.60	82.08	36.46	0.32	18.03	94.49
CL 255	2.76	0.43*	0.31	91.30	38.58	-0.30	45.10	89.29
CL 260	2.75	-0.17*	0.43*	91.64	43.71	-0.63	19.88	78.81
CL 262	3.14	1.63	2.24	80.25	36.69	-1.28*	30.98	93.89
CL 263	2.91	1.24*	0.29*	86.60	40.58	-0.17*	0.98*	84.89
CL 269	2.79	0.04	0.41*	90.32	36.25	1.85	42.10	95.03
Population mean	37.33	1.00			3.23	1.07		
SE (mean)	2.61	0.58			0.55	0.34		

Table 4. Stability parameters for rhizome yield per plant in turmeric.

Genotype	Rhizome yield per plant (kg)			
	Mean	b_i	S^2d_i	Sustainability index
CL 2	0.592	1.68	0.05*	62.33
CL 15	0.473	1.54	0.02	78.01
CL 22	0.402	0.83	0.01	91.79
CL 35	0.466	1.07	0.01	79.18
CL 41	0.480	1.51	0.01	76.88
CL 42	0.497	1.17	0.01	74.25
CL 43	0.371	0.73	0.00*	99.46
CL 49	0.439	1.10	0.00*	84.05
CL 52	0.481	1.36	0.03	76.72
CL 74	0.396	0.60	0.00	93.18
CL 75	0.470	1.07	0.01	78.51
CL 78	0.389	0.64	0.00	94.86
CL 88	0.312	0.19	0.01	118.27
CL 89	0.370	-0.22	0.01*	99.73
CL 100	0.560	1.22	0.02	65.89
CL 114	0.420	1.15	0.00	87.86
CL 120	0.500	1.41	0.01	73.80
CL 121(C)	0.499	1.73	0.00	73.95
CL 122	0.512	1.62	0.00	72.07
CL 130	0.397	0.84	0.01	92.95
CL 131	0.328	0.63	0.01	112.50
CL 132	0.349	0.67	0.01	105.73
CL 133	0.380	0.63	0.01	97.11
CL 134	0.401	0.55	0.02	92.02
CL 135	0.415	0.76	0.02	88.92
CL 144	0.456	1.12	0.00	80.92
CL 146	0.499	1.22	0.00	73.95
CL 147	0.508	1.35	0.01	72.64
CL 148	0.390	0.58	0.00	94.62
CL 149	0.390	0.82	0.01	94.62
CL 151	0.394	0.72	0.00	93.65
CL 152 (C)	0.426	1.10	0.01	86.62
CL 156	0.451	1.08	0.01	81.82
CL 158	0.464	1.12	0.01	79.53
CL 169	0.477	1.46	0.03	77.36
CL 172	0.412	1.21	0.01	89.56
CL 173	0.351	0.95	0.01	105.13
CL 174	0.322	0.73	0.01	114.60
CL 175	0.397	1.30	0.01	92.95
CL 184	0.365	0.51	0.01	101.10
CL 189 (C)	0.375	1.05	0.01	98.40
CL 192	0.407	1.05	0.01	90.66
CL 194	0.332	0.50	0.01	111.14
CL 195	0.395	0.93	0.00	93.42
CL 198	0.362	0.75	0.00	101.93
CL 199	0.414	1.02	0.00	89.13
CL 200	0.461	1.02	0.01	80.04
CL 201	0.448	0.92	0.00	82.37
CL 209	0.407	1.27	0.00	90.66
CL 213	0.503	1.22	0.01	73.36
CL 255	0.456	1.10	0.00	80.92
CL 260	0.422	1.27	0.02	87.44
CL 262	0.400	0.94	0.02	92.25
CL 263	0.424	0.83	0.01	87.03
CL 269	0.532	1.39	0.00	69.36
Population mean	0.430	1.00		
SE (mean)	0.47	1.10		

environments. CL 88, which showed suitability for favorable environments also showed high SI indicating consistent performance over years in favorable environments. In terms of plant height, a total of 35 genotypes were recognized as suitable for broader adaptability based on stability parameters (Table 2). Among these, seven genotypes exhibited a very high stability index (SI) exceeding 100%, while an additional 26 genotypes demonstrated a high SI ranging from 80% to 100%. Notably, CL 88 and CL 174, which were deemed suitable for favorable environmental conditions, also displayed a high SI. All the genotypes namely CS 101, CS 187, CS 228, CS 229, CS 238, and CS 240 identified as suitable for the unfavorable environment, recorded very high SI, indicating their consistent performance over years. In case of number of tillers per plant, the genotypes qualified for wider adaptation, namely, CL 78, CL 89, CL 144, CL 148, CL 149, CL 154, CL 182, CL 194, CL 198, and CL 200 for favorable environments showed very high SI (Table 3). On the basis of the above findings, it can be concluded that genotypes, *viz*., CL 100, CL 122, CL 147, CL 213, and CL 269, through the stable performance of major yield contributing traits like number of leaves per plant, number of tillers per plant and rhizome yield per plant. These genotypes may be useful genetic resources for the development of high yielding, stable varieties of turmeric.

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