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Morpho-physiological Changes in Maize Genotype under Water Stress Condition at Pre and Post Flowering Stages

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ABSTRACT: Production of maize is severely affected by water deficit during teaselling and grain filling stage and it has been estimated to cause average annual yield losses about 17% in the world. It is highly sensitive to water stress in the period from one week before to two weeks after flowering, leading to grain abortion. Therefore, the present investigation was carried out to investigate the effect of water stress on morpho-physiological parameters of thirty genotypes of maize grown under control and water stress field conditions. The highly significant differences were observed for all the parameters studied. Anthesis-Silking interval was increased and rest of the parameters were found to be reduced under stress condition. Cob weight per plant and number of grains per cob had a positive significant correlation with grain yield per plant in both the conditions. Performance (Increase/decrease percent) based rank of genotypes for various parameters under study and minimum reduction percent in grain yield per plant, genotypes GWC-9631, PM-3, GWC-9611, GYC-9325, EH-1491 and GM-2 had an identified as water stress tolerance genotypes of maize.

Keywords: Grain yield, maize, morpho-physiological parameters, water stress.

INTRODUCTION

Water stress is considered to be one of the most important abiotic factor to affect the plant growth, development and productivity of the crop (Hassan *et al.*, 2016). In addition, the adverse impacts on social and economic life of mankind (Anjum *et al.*, 2012) as well as impairing crop production (Hamrouni *et al.*, 2001). The adaptability and responses of the plants to water stress depends on duration, magnitude of stress and developmental stage of the plant (Kramer and Boyer, 1995). Maize (*Zea mays* L.) is one of the most important cereal crop in the world agricultural economy, both as food for man and feed for animals and its serves as a source for high fructose syrup, malt dextrin, germ oil, germ meal fibre and gluten products which have application in industries such as alcohol, textile, paper, pharmaceuticals, organic chemicals, cosmetics and unsaturated fatty acids (Sabagh *et al.*, 2018). Maize is particularly sensitive to water stress in the period from one week before to two weeks after flowering (Grant *et al.*, 2007). Drought during these period results in an easily measured increase in the anthesis-silking interval as silk emergence and spikelet emergence is delayed (Banziger *et al.*, 2000; Edmeades *et al.*, 2000) leading to grain abortion (Boyle *et al.*, 1991). Grain abortion commonly occurs during the first 2 to 3 weeks after silking (Westgate and Boyer, 1986). In India, maize is grown round the year in many states but mainly in *kharif* season, which accounts for about 85 percent of the total maize area in the country. Among various abiotic stresses, extremes of water availability, drought or excess soil moisture are the major limiting factors for maize production and productivity (Andrade *et al*., 1996; Tollenaar and Lee, 2002). Traditional breeding strategies that have attempted to utilize genetic variation arising from varietal germplasm, hybridization and mutations have met with limited success. Morpho-physiological, biochemical and stress tolerance indices are useful tools to determine high productivity and stress tolerance potential of genotypes of crop. It has been studied and identifying high productive genotypes under stress and non-stress conditions are more beneficial than the developing new verities (Lan, 1988; Mitra, 2001; Jafari *et al*., 2009; Mittal *et al*., 2009; Naghavi *et al*., 2013; Barutçular *et al*., 2016a; Mittal and Singh, 2021). Therefore, present study was conducted aimed to investigate the morpho-physiological changes and also attempt to identify the maize genotypes tolerant to water deficit stress condition.

MATERIALS AND METHOD

Seeds of thirty diverse maize genotypes were obtained from the Main Maize Research Station, Godhra, Anand Agricultural University, Anand, Gujarat and All India Coordinate Research Project on Maize, Maharana Pratap University of Agriculture and Technology, Udaipur (Rajasthan). These genotypes were sown in two replications with two stress conditions namely control (S_0) and water stress (S_1) at pre and post flowering stages at Agronomy Farm, B. A. College of Agriculture, Anand in *Rabi* season during 2009-10. Irrigation was given at time of seed sowing for establishing the crop in both stress conditions. Pre and post flowering stages which commensurate with 50-60 and 80-90 days after sowing in most of the genotypes. Water stress condition was created by withholding irrigation in one set of genotypes while other set of genotypes was given normal irrigation pre and post flowering stages. Soil of the experimental block was sandy loam with moderate water holding capacity and was uniformly provided with organic manure in the form of FYM. All recommended agronomic practices were carried out during entire cropping season except irrigation. Plant protection measures were also adopted as and when required. Observations were recorded ten randomly selected plants of each genotype in each replication and each environments avoiding unhealthy and border plants under control (S_0) and water stress (S_1) conditions. Anthesis-silking interval (ASI) (days) and total chlorophyll content (mg per g fresh weight) were recorded after 10 days of imposing water stress at pre and post flowering stages. Cob weight per plant (g), number of grains per cob and grain yield per plant (g) were recorded at the time of harvesting of crop. Total chlorophyll content (mg per g fresh weight) was measured as per Hiscox and Israelstam (1979). All the studied parameters were subjected to pooled analysis of variance, to determine the significance difference of among genotypes, environment and genotype × environment interaction effect (Gomez and Gomez, 1984). The Pearson correlation coefficient between grain yield per plant and morpho-physiological parameters were estimated using SPSS 20.0 statistical software (SPSS, 2011).

RESULTS AND DISCUSSION

Pooled analysis of variance for morpho-physiological parameters showed highly significant differences among the stress, genotypes and stress × genotype interaction for all the parameters studied, namely, anthesis-silking interval, total chlorophyll content, cob weight per plant, number of grains per cob and grain yield per plant (Table 1). These indicate that stress have significantly influenced the expression of the parameters among the genotypes, in other words the genotypes performance was influenced by the stress condition. The significant differences among the genotypes indicate that variation among the genotypes were heritable. Significant stress × genotypes indicated that there was differential response of genotypes to stress. The similar results were reported by Singh *et al.*, (2015) in pearl millet, Meena *et al*., (2016) in fenugreek and Mittal and Singh (2021) in maize.

Table 1: Pooled analysis of variance for the parameters under study.

Source of variance	d. f.	ASI	TC content	Cob weight/plant	No. of grains/cob	Grain yield/plant
		MSS				
Stress	1	313.63**	477.98**	3829.72**	10279.11**	3049.49**
Genotypes	29	5.84**	58.12**	367.02**	3813.16**	220.80**
S × G	29	1.81**	11.45**	177.49**	3693.97**	117.35**
Pooled Error	58	0.55	0.82	74.74	1954.79	42.05

Morpho-physiological parameters were observed significant differences in thirty genotypes of maize under control (S_0) and stress (S_1) conditions are shown in Table 2 and 3. Anthesis-silking interval was ranging from 1.0 to 5.50 days in genotypes EH-1820 and EC-3135 in S_0 and 2.50 to 10.50 days in genotypes EH-1731 and EC-3135 in S_1, respectively. Anthesis-silking interval was 57.16 percent increase in average mean value of all the genotypes in water stress at pre and post flowering stages and genotype EH-3135 having highest value followed by genotypes GYC-9837, GWC-0204, EC- 3154, GM-6 and GYC- 0402 in S_1. Genotype GYC-9646 has no change in rank in S_0 and S_1 conditions and genotypes EC-3160, GWC-9631, GYC-9327, EH-1731 and PM-3 were found least percent increase and genotypes GWC-0204, GWC-9626, GYC-9315 and EH-1389 were found higher percent increase from S_0. Total chlorophyll content was ranging from 11.14 to 25.13 in genotypes GWC-9604 and GWC-9631 in S_0 and 5.58 to 20.51 in genotype GYC-9837 and GM-2 in S_1, respectively. Total chlorophyll content was 31.77 percent decrease in average mean value of all the genotype due to water stress condition and genotype GM-2 had highest value followed by genotypes GWC-0204, GWC-9631, GYC-9635 and EH-1820 in S_1. Rank wise genotype GM-6 was not change in water stress condition and genotypes EC-3160, GYC-9646, GWC-9604, Texpeno sequia and GWC-9103 were found least percent decrease and genotypes EH-1731, EC-3135, EH-1389 and GYC-0402 were found higher percent decrease in S_0. The reduction in total chlorophyll content under water stress may be due to the reduction in formation and restructure in the formatted pigments (Misra *et al.*, 1997). Reactive oxygen species generated due to prolonged stress conditions may have an adverse impact on photosynthetic apparatus of the cell by damaging chlorophyll (Mittova *et al.*, 2000; Agarwal *et al.*, 2013). Total chlorophyll content decreased significantly in all the genotypes at pre and post flowering stages during water stress condition. Least decrease in total chlorophyll content in some genotypes indicated that their photosynthetic apparatus is able to resistant adverse condition due to water stress (Singh and Rajpoot, 2021). Cob weight per plant was ranging from 38.89 to 80.90 in genotype Texpeno sequia and EC-3157 in S_0 and 21.21 to 77.46 in genotype GWC-9101 and EC-3160 in S_1, respectively.

Table 2: per se performance of stress and genotypes for various parameters under study.

Treatment	ASI	TC content	Cob weight/plant	No. of grains/cob	Grain yield/plant
Stress (S)					
Control (S_0)	2.42	16.55	60.69	264.41	49.14
Stress (S_1)	5.65	12.56	49.39	245.90	39.05
SEm	0.096	0.117	1.116	5.708	0.837
CD at 0.05(%)	0.27	0.33	3.16	16.16	2.37
Genotypes (G)					
PM-3	2.38	15.00	63.96	292.05	49.97
EC-3135	8.00	8.85	56.02	261.05	50.53
EC-3160	5.25	14.56	75.49	280.45	53.75
EC-3157	4.75	13.48	63.09	270.75	48.48
GWC-9611	3.75	13.22	44.32	272.10	36.59
GYC-9646	3.38	11.89	63.38	283.50	49.75
GWC-9103	4.38	15.52	44.85	220.85	34.70
GWC-9701	4.00	10.77	48.06	222.30	35.15
GYC-0402	4.75	15.27	54.48	251.70	42.80
EH-1491	4.63	16.66	55.72	224.50	42.01
GWC-9101	4.00	10.99	46.85	258.70	38.47
EH-1389	3.50	8.53	61.33	231.05	47.66
GYC-9325	3.75	12.09	62.69	279.35	48.23
GYC-9837	5.50	9.89	46.17	247.15	39.67
GWC-9604	3.75	10.94	46.96	224.55	39.83
GWC-9626	2.75	14.90	48.57	245.45	41.02
GYC-9005	3.75	12.84	59.26	294.20	46.79
GYC-9327	3.25	16.70	53.44	263.85	47.86
GWC-9631	5.00	21.72	53.45	242.70	40.60
GWC-9413	4.25	11.15	50.44	232.70	37.56
GYC-9535	3.00	21.04	60.76	246.30	43.93
GYC-0401	3.75	15.47	67.86	266.45	47.08
GM-6	4.50	17.55	49.37	270.70	39.25
GM-2	3.75	21.96	64.10	322.10	54.31
EC-3154	5.50	11.90	43.47	234.75	39.08
Texpeno sequia	4.00	14.23	37.32	167.40	23.52
EH-1820	2.00	19.85	55.57	252.35	52.61
GYC-9315	2.75	16.82	47.22	223.70	39.76
EH-1731	2.00	11.76	77.64	268.65	57.96
GWC-0204	5.00	21.11	49.27	303.20	53.90
SEm	0.6718	1.692	6.661	30.389	5.416
CDat 0.05 (%)	1.94	4.89	19.26	86.04	15.66
S × G	Significant	Significant	Significant	Significant	Significant
CV	18.38	6.23	15.71	17.33	14.71

Table 3: Effect of water stress on various parameters under study.

Genotypes	ASI			TC content			Cob weight/plant			No. of grains/cob			Grain yield/plant		
	S_0	S_1	I (%)	S_0	S_1	D (%)	S_0	S_1	D (%)	S_0	S_1	D (%)	S_0	S_1	D (%)
PM-3	1.8	3.0	41.7	16.1	13.9	13.2	62.2	65.7	-5.6	286.8	297.3	-3.7	50.4	49.6	1.7
EC-3135	5.5	10.5	47.6	12.0	5.7	52.3	63.2	48.9	22.6	278.1	244.0	12.3	53.1	48.0	9.7
EC-3160	4.5	6.0	25.0	14.6	14.5	1.0	73.5	77.5	-5.4	254.2	306.7	-20.7	58.1	49.4	14.9
EC-3157	3.0	6.5	53.8	14.2	12.7	10.5	80.9	45.3	44.0	284.1	257.4	9.4	55.0	42.0	23.6
GWC-9611	2.5	5.0	50.0	13.8	12.7	7.7	45.8	42.8	6.5	266.2	278.0	-4.4	37.1	36.0	2.9
GYC-9646	1.8	5.0	65.0	12.0	11.8	1.3	65.5	61.3	6.4	278.2	288.8	-3.8	54.6	44.9	17.7
GWC-9103	2.8	6.0	54.2	16.1	14.9	7.3	56.7	33.0	41.8	249.0	192.7	22.6	43.1	26.4	38.8
GWC-9701	2.5	5.5	54.5	11.4	10.1	11.6	54.0	42.1	22.1	219.4	225.2	-2.6	38.3	32.0	16.4
GYC-0402	2.5	7.0	64.3	19.7	10.8	45.2	62.8	46.2	26.5	257.2	246.2	4.3	50.7	34.9	31.2
EH-1491	2.8	6.5	57.7	17.6	15.7	10.4	59.1	52.4	11.4	222.9	226.1	-1.4	42.8	41.2	3.8
GWC-9101	2.0	6.0	66.7	11.7	10.3	12.5	72.5	21.2	70.7	355.6	161.8	54.5	55.4	21.5	61.2
EH-1389	1.5	5.5	72.7	11.5	5.6	51.4	76.3	46.4	39.1	267.8	194.3	27.4	60.8	34.5	43.3
GYC-9325	2.0	5.5	63.6	14.1	10.1	28.2	59.2	66.2	-11.7	230.8	327.9	-42.1	47.1	49.4	-4.7
GYC-9837	2.5	8.5	70.6	11.2	8.6	22.6	56.8	35.5	37.5	299.9	194.4	35.2	54.2	25.2	53.5
GWC-9604	2.5	5.0	50.0	11.1	10.7	3.7	52.7	41.2	21.8	248.6	200.5	19.3	47.1	32.6	30.9
GWC-9626	1.0	4.5	77.8	19.2	10.6	45.0	50.7	46.5	8.4	239.5	251.4	-5.0	45.0	37.1	17.5
GYC-9005	2.5	5.0	50.0	15.8	9.9	37.3	65.1	53.5	17.8	318.9	269.5	15.5	51.3	42.3	17.5
GYC-9327	2.5	4.0	37.5	18.5	14.9	19.2	61.1	45.8	24.9	290.3	237.4	18.2	54.8	40.9	25.3
GWC-9631	4.0	6.0	33.3	25.1	18.3	27.1	49.0	57.9	-18.1	224.9	260.5	-15.8	38.0	43.2	-13.8
GWC-9413	2.5	6.0	58.3	12.2	10.1	17.7	56.6	44.3	21.8	213.0	252.4	-18.5	39.5	35.6	10.0
GYC-9535	1.5	4.5	66.7	24.8	17.3	30.3	65.8	55.7	15.4	232.2	260.4	-12.1	45.8	42.0	8.4
GYC-0401	2.5	5.0	50.0	17.0	14.0	17.9	66.1	69.7	-5.4	291.7	241.2	17.3	54.2	39.9	26.4
GM-6	2.0	7.0	71.4	19.9	15.2	24.0	63.8	34.9	45.3	289.3	252.1	12.9	44.0	34.5	21.4
GM-2	2.5	5.0	50.0	23.4	20.5	12.4	72.6	55.6	23.4	323.1	321.1	0.6	53.8	54.8	-1.9
EC-3154	4.0	7.0	42.9	14.0	9.8	29.8	49.8	37.1	25.5	237.6	231.9	2.4	42.5	35.6	16.3
Texpeno sequia	2.5	5.5	54.5	14.6	13.9	4.5	38.9	35.8	8.0	151.1	183.7	-21.6	30.0	17.1	43.0
EH-1820	1.0	3.0	66.7	23.9	15.8	33.8	62.5	48.6	22.2	256.1	248.6	2.9	53.9	51.4	4.6
GYC-9315	1.0	4.5	77.8	24.5	9.1	62.8	49.6	44.9	9.6	226.2	221.2	2.2	40.7	38.9	4.4
EH-1731	1.5	2.5	40.0	13.7	9.8	28.3	79.8	75.4	5.5	252.5	284.8	-12.8	59.3	56.6	4.4
GWC-0204	1.5	8.5	82.4	22.9	19.3	15.6	48.0	50.6	-5.5	387.0	219.4	43.3	74.5	33.3	55.3
Mean	2.4	5.7	57.2	16.6	12.6	24.1	60.7	49.4	18.6	264.4	245.9	7.0	49.1	39.1	20.5
S Em	0.5241			0.641			6.113			31.263			4.585		
CD at 0.05 %	1.48			1.82			17.31			88.51			12.98		

I (%) = Increase percent and D (%) = Decrease percent

Cob weight per plant was 22.88 percent decrease in average mean value of all the genotype due to water stress condition and genotype EC-3160 had highest value followed by genotypes EH-1731, GYC-0401, GYC-9325 and PM-3 in S_1. Genotypes GYC-9005, GYC-9535, EC-3154, EH-1820 and EH-1731 were found same rank in S_0 and S_1 environments and genotypes GWC-9631, GYC-9325, PM-3, GWC-0204 and GYC-0401 were found no percent decrease and genotypes GWC-9101, GM-6, EC-3157 and GWC-9103 were found higher percent decrease from S_0. Number of grains per cob was ranging from 151.10 to 387.00 in genotype Texpeno sequia and GWC-0204 in S_0 and 161.80 to 327.90 in genotype GWC-910 and GYC-9325 in $S_{1,}$ respectively. Number of grains per cob was 7.50 percent decrease in average mean value of all the genotype due to water stress condition and genotypes GYC-9325 had highest valve followed by genotypes GM-2, EC-3160, PM-3 and GYC-9646 in S_1. Genotypes EC-3157, GY-0402 and EH-1820 were found similar rank in S_0 and S_1 conditions and genotypes GYC-9325, Texpeno sequia, EC-3160, GWC-9413 and GW-9631 were found no percent decrease and genotypes GWC-9101, GWC-0204, GYC-9837 and EH-1389 were found higher percent decrease from S_0. Grain yield per plant was ranging from 29.97 to 74.52 in genotype Texpeno sequia and GWC-0204 in S_0 and 17.07 to 56.64 in genotype Texpeno sequia and EH-1731in $S_{1,}$ respectively. Grain yield per plant was showed 25.98 percent decrease in average mean value in all the genotypes during water stress at pre and post flowering stages and genotype EH-1731 had highest value followed by genotypes GM-2, EH-1820, PM-3 and EC-3160 in S_1. Genotypes GYC-9649, Texpeno sequia, EC-3160, GWC- 9701, GM-6 and EH-1731 were found similar rank in S_0 and S_1 conditions and genotypes GWC-9631, GYC-9325, GM-2, PM-3 and GWC-9611 were found no percent decrease and genotypes GWC-9101, GWC-0204, GYC-9837 and EH-1389 were found higher percent decrease in S_0. Drought stress is prolonged over to a certain period, will inevitably result in oxidative damage due to the over production of reactive oxygen species. Genotypes GWC-9631, GYC-9325, GWC-9611and GM-2 were produce less grain yield and least affected by water stress. Water stress at pre and post flowering stages of plant might alter the seed composition and related qualities (Anwar *et al.*, 2006). The decrease in growth, yield and quality characters under water stress is a common phenomenon (Ali *et al*., 2009; Singh and Rajpoot, 2021). However, withholding irrigation at pre and post flowering stage showed increased days in anthesis-silking interval and decreased in total chlorophyll content, cob weight per plant, number of grains per cob and grain yield per plant in most of the genotypes.

The most desirable parameters were determined under stress condition at pre and post flowering stages, by used of Pearson correlation coefficient between morpho-physiological parameters (Table 4). ASI showed a negative non-significant correlation with total chlorophyll content (-0.274; -0.174), cob weight per plant (-0.006; -0.349), number of grains per cob (-0.093; -0.299) and grain yield per plant (-0.127; -0.348), total chlorophyll content had a positive non-significant correlation with number of grains per cob (0.053; 0.251) and grain yield per plant (0.002; 0.178), cob weight per plant has a positive significant correlation with number of grains per cob (0.384; 0.753) and grain yield per plant (0.579; 0.794) and number of grain per cob showed a positive significant correlation with grain yield per plant (0.774; 0.835) under S_0 and S_1 conditions indicating that genes controlling grain yield and drought tolerance are different (Rosielle and Hamblin, 1981). The best morpho-physiological parameters are those which have positive significant correlation with grain yield per plant in both S_0 and S_1 conditions would be able to identify higher yielding and drought tolerant genotypes (Talebi *et al*., 2007; Singh and Rajpoot, 2021).

Table 4: Correlation coefficient between parameter under both the environmental conditions.

Parameters	Levels	ASI	TC content	Cob weight/plant	No. of grains/cob	Grain yield/plant
ASI	S_0	-	-0.274	-0.006	-0.093	-0.127
	S_1	-	-0.174	-0.349	-0.299	-0.348
TC content	S_0		-	-0.149	0.053	0.002
	S_1		-	0.190	0.251	0.178
Cob weight/plant	S_0			-	0.384*	0.579**
	S_1			-	0.753**	0.794**
Number of grains/cob	S_0				-	0.774**
	S_1				-	0.835**
Grain yield/plant	S_0					-
	S_1					-

*and ** represent significant at 5 (%) and 1(%) level of significant, respectively

Rank based performance (Increase/decrease percent) of genotype for various parameters studied and minimum reduction percent in grain yield per plant (Table 5), genotypes GWC-9631, PM-3, GWC-9611, GYC-9325, EH-1491 and GM-2 had an identified as water stress tolerance. Genotype EC-3160 has a lowest rank for all parameter under study but lower rank in grain yield. Genotypes EH-1389, GWC-9101, GYC-9837, GYC-0402 and GM-6 have a highest rank of all parameter and more reduction, it means these genotypes showing susceptible to water stress. These results are in agreement with the findings of Singh *et al*., (2015) in pearl millet, Meena *et al*., (2016) in fenugreek and Mittal and Singh (2021) in maize.

Table 5: Performance (increase/decrease percentage) based rank of genotypes for various parameters under study.

Genotypes	ASI	TC content	Cob weight/plant	No. of grains/cob	Grain yield/plant	Total Rank	Rank
PM-3	5	12	3	11	4	35	3
EC-3135	7	29	20	20	11	87	19
EC-3160	1	1	6	3	13	24	1
EC-3157	13	8	28	19	20	88	20
GWC-9611	8	6	9	9	5	37	4
GYC-9646	21	2	8	10	18	59	10
GWC-9103	14	5	27	26	25	97	24
GWC-9701	15	9	18	12	15	69	12
GYC-0402	20	27	24	18	24	113	26
EH-1491	17	7	13	13	6	56	7
GWC-9101	22	11	30	30	30	123	28
EH-1389	27	28	26	27	27	135	30
GYC-9325	19	20	2	1	2	44	5
GYC-9837	25	17	25	28	28	123	28
GWC-9604	8	3	17	25	23	76	14
GWC-9626	28	26	11	8	17	90	21
GYC-9005	8	25	15	22	16	86	17
GYC-9327	3	16	22	24	21	86	17
GWC-9631	2	19	1	5	1	28	2
GWC-9413	18	14	16	4	12	64	11
GYC-9535	22	23	14	7	10	76	14
GYC-0401	8	15	5	23	22	73	13
GM-6	26	18	29	21	19	113	26
GM-2	8	10	21	14	3	56	7
EC-3154	6	22	23	16	14	81	16
Texpeno sequia	15	4	10	2	26	57	9
EH-1820	22	24	19	17	9	91	22
GYC-9315	28	30	12	15	7	92	23
EH-1731	4	21	7	6	8	46	6
GWC-0204	30	13	4	29	29	105	25

CONCLUSION

Genotypes GWC-9631, PM-3, GWC-9611, GYC-9325, EH-1491 and GM-2 were showed a stable performance and percent least reduction for morpho-physiological parameters and grain yield at pre and post flowering stages in water stress condition. However, these genotypes may be used in future breeding programme.

FUTURE SCOPE

The above selected genotypes could be used in the breeding programme in the development of new varieties/hybrids against water stress tolerance. Furthermore, these genotypes also frame a path for researchers and breeders in the selection of locally available such superior germplasms. Further, investigation is needed to elucidate the mechanism of such genotypes with respect to climate resilience and adverse conditions.

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