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Impact of Stress Induced by Unfavorable Soil Conditions on the Germination, Seedling Developmentand Stress Tolerance Indices of Browntop Millet (*Brachiaria ramosa* L.)

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ABSTRACT

Background: Browntop millet, a traditionally cultivated yet underutilized millet, is abundant in iron, zincand fiber. It can thrive in diverse soils and climates, adapting well to a broad spectrum of ecological conditions. Assessing the performance of Brown top millet in various challenging soils prevalent across Tamil Nadu could provide valuable insights into its adaptability and potential for cultivation in different soil conditions. The evaluation focuses on its germination, seedling growthand stress tolerance indices in these diverse soil environments.

Methods: The pot experiment was carried out in the Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore during *Kharif* 2023 season. Six soil types were collected from different zones in Tamil Nadu and tested in a completely randomized design with four replications. Germination, seedling growth and stress tolerance indices were calculated by using standard formula.

Result: Results of the investigation revealed that the treatment with sandy clay loam soils of Eastern Block 37B TNAU, Coimbatore (T1) recorded higher germination and seedling growth indices. The lowest values were recorded with the sodic soils of ADAC and RI, Trichy (T6). The higher stress tolerance indices were recorded with the heavy clay soils of Cotton Research Station (CRS), Veppanthattai, Perambalur district (T2)and acidic soils of Anaikatti, Coimbatore district (T3).

Key words: Browntop millet, Germination, Growth, Problematic soils, Stress tolerance.

INTRODUCTION

The Earth's varied terrains contribute to a diverse array of soil types, each possessing distinct features and obstacles. As an essential element of ecosystems, soils are pivotal in sustaining life, particularly in the realm of agriculture. Nonetheless, not all soils support vigorous plant growth and sustainable land utilization. Some soils, termed "problematic soils," are the present challenges that impact agricultural productivity and environmental sustainability. These challenges can range from issues related to soil structure, nutrient imbalance, water retention, soil erosion, salinity, alkalinity, acidity, limited microbial activity, land degradation and crop selection challenges. Crop selection in problematic soils poses unique challenges due to the specific characteristics and limitations of these soils. Millets can be a suitable choice for cultivation in certain problematic soils due to their adaptability and resilience. Certain millet crops, like pearl millet (*Pennisetumglaucum*), have demonstrated resilience to saline soils, exhibiting an ability to endure elevated levels of soil salinity and alkalinity surpassing that of several other crops (Lokur *et al.,* 2023). Finger millet (*Eleusinecoracana*) has established a notable capability to thrive in acidic soils (Ceasar *et al.,* 2023). Furthermore, both foxtail millet (*Setariaitalica*) and proso millet (*Panicummiliaceum*) are recognized for their adaptability to diverse soil conditions, encompassing those with mild acidity (Lokur *et al.,* 2023). Similarly, just like other millets that showcase the capacity to withstand increased levels of soil salinity, alkalinityand acidity, there is a need to explore the potentiality of traditionally grown, underutilized Browntop millet in these aspects. Browntop millet (*Brachiaria ramosa* L.) is an introduced annual grass from the Poaceae family, originating in South East Asia, known for its adaptability to diverse soil and climatic conditions. This highly nutritious and resilient millet holds a unique characteristic among its counterparts- it is shade tolerant (Ambati *et al.,* 2024). With its largely unexplored capability to accumulate lead and zinc in plant tissues, Browntop millet emerges as a potential candidate for remediating soils contaminated with these metals, as emphasized by (Rathore *et al.,* 2023). Beyond its remediation potential, Browntop millet serves multiple agricultural purposes. It can be cultivated as a catch crop,

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cover cropand nurse cropand its robust biomass production makes it suitable for soil erosion control (Maitra *et al.,* 2023). The nutritional profile of Browntop millet is impressive, with every 100 grams providing 8.98 gm of protein, 1.89 gm of fat, 71.32 gm of carbohydrates, 8.06 gm of crude fiber, 1414 kj of energy, 28 mg of calciumand 8.86 mg of iron (Singh *et al.,* 2022). This millet not only addresses the challenge of remediating contaminated soils but also emerges as a solution to combat malnutrition and lifestyle diseases (Reddy and Prasad, 2017). Its nutritional richness contributes to food security, aligning with the principles of sustainable agriculture. Browntop millet, with its versatility and nutritional benefits, stands as a promising crop for multifaceted agricultural and environmental objectives. In this context, a pot experiment was conducted to assess the efficacy of Browntop millet in challenging soil conditions. The main objective is to assess germination, seedling growthand stress tolerance indices.

MATERIALS AND METHODS

A pot experiment was undertaken in the Department of Agronomy, Tamil Nadu Agricultural University (TNAU), Coimbatore, Tamil Nadu, during the *Kharif* season of 2023-2024 (June-September). This investigation was laid out in a completely randomized design with six treatments and 4 replications. The soils were gathered from different zones in Tamil Nadu. The places from where the soils were collected are mentioned below as treatments

Treatments

T_1- Sandy clay loam soils of Eastern Block 37B TNAU, Coimbatore (Control).

T_2- Heavy clay soils of Cotton Research Station (CRS), Veppanthattai, Perambalur district.

T_3- Acidic soils of Annaikatti, Coimbatore district.

T_4- Coastal saline soils of Cuddalore district.

T_5- Waterlogged soils of Agricultural Research Station (ARS), Bhavani Sagar, Erode district.

T_6- Sodic soils of ADAC and RI, Trichy district.

The soils were collected from the top 30 cm layer of the fields at representative sites. The soil types and their characteristics are given in Table 1. The physical properties of initial soil samples were tested by Robinson's International Pipette method (Piper, 1966). The pH and EC of the soil were determined in 1:2.5 soil-water suspension using an Elico pH meter with a glass electrode and electrical conductivity meter as described by Jackson (1973). The organic carbon of the soil sample was determined by using the wet digestion method (Walkley and Black, 1934). The available N, P and K were determined by the alkaline KMnO4 method as suggested by Subbiah and Asija (1956), Olsen's extractant method by Olsen *et al.* (1954) and neutral normal ammonium acetate method by using a flame photometer by Jackson, 1973 respectively. Each pot was filled with 6 kg of air-dried soil and 20 seeds of Browntop millet were sown on the surface of the soil and covered with a thin layer of soil. The pots were arranged randomly during the investigation. No fertilizers were supplied to pots to assess the impact of stress induced by unfavorable soil conditions on Brown top millet production. Irrigation was given when required. Germination was counted at 24-hour intervals and continued up to the 10^{th} day. A seed was considered germinated as plumule and radicle came out and was>2 mm long. Root length and shoot length were measured using a ruler. Five germination characteristics namely final germination percentage, germination energy (%), coefficient of velocity of germination, germination index and seedling vigor index were estimated.

Final germination percentage (FGP)

Seed germinated count was taken after 8 days from the sowing date and expressed as a percentage according to the following equation described by (Roberts, 1981).

Germination percentage

The germination index and seed vigor index (SVI) were calculated from a formula documented by (Mishra *et al.,* 2019).

Germination percentage =

$$\frac{\text{Number of seeds germinated}}{\text{Total number of seeds tested}} \times 100$$

Germination index (GI)

Germination index = n11+n22+…nxx

Where,

n1…nx are the number of seeds germinated on day 1 to day x1…x is the number of days.

Seedling vigor index

Seedling vigor index =

$$\frac{\text{Germination percentage} \times \text{root length + shoot length}}{100}$$

Coefficient of velocity of germination (%)

Coefficient of velocity of germination (%) =

$$\frac{N1 + N2 + \cdots + Nx}{[N1T1 + \cdots + NxTx]} \times 100$$

(Jones and Sanders,1987)

N= No. of seeds germinated each day.

T= No. of days from seeding corresponding to N.

Germination energy (%)

$$\frac{\text{Number of seeds germinated after 3 days}}{\text{Total number of seeds tested}} \times 100$$

(Avdeeva *et al.,* 2018)

Stress tolerance indices were calculated using the following formulae given by (Ashraf *et al.,* 2006).

Plant height stress tolerance index (% over control)

$$\frac{\text{Plant height of stressed plant}}{\text{Plant height of control plants)}} \times 100$$

Root length stress tolerance index (% over control)

$$\frac{\text{Root length stressed plant}}{\text{Root length of control plants}} \times 100$$

Seedling vigor index (% over control)

$$\frac{\text{Vigor of stressed plant}}{\text{Vigor of control plants}} \times 100$$

The collected data were subjected to statistical analysis (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Soil characteristics

The physical and chemical properties of the soil used in this trial are shown in Table 1. The texture of sandy clay loam soils of Eastern Block 37B TNAU, Coimbatoreand sodic soils of ADAC and RI, Trichy district is sandy clay loam, while acidic soils of Annaikatti, Coimbatore districtand waterlogged soils of Agricultural Research Station (ARS), Bhavani Sagar, Erode district exhibit a clay loam texture. The heavy clay soils of Cotton Research Station (CRS), Veppanthattai, Perambalur district have a clay texture. The coastal saline soils of Cuddalore district, on the other hand, possess a sandy loam texture. The pH of the soils ranged from normal to saline (7.3-8.5) except for the soils of Annaikatti, Coimbatore district which was acidic in nature (5.65) and the soils of ADAC and RI, Trichy district which were alkaline in nature (8.92). The electrical conductivity of the soils examined in this study varied between 0.22-0.62 dSm^{-1}, classifying them as non-saline, except for the coastal saline soils of Cuddalore district, which registered an EC of 2.4 dSm^{-1}, categorizing them as saline. The organic carbon content in the soils gathered from the coastal saline soils of Cuddalore district, waterlogged soils of Agricultural Research Station (ARS), Bhavani Sagar, Erode districtand sodic soils of ADACand RI, Trichy district were characterized as low. In contrast, it is high for the sandy clay loam soils of Eastern Block 37B TNAU, Coimbatore, the heavy clay soils of Cotton Research Station (CRS), Veppanthattai, Perambalur districtand the acidic soils of Annaikatti, Coimbatore district. The levels of available nitrogen in the soils collected from the coastal saline soils of Cuddalore district and sodic soils of ADAC and RI, Trichy district were low. Conversely, it is moderate in the sandy clay loam soils of Eastern Block 37B TNAU, Coimbatore, the heavy clay soils of Cotton Research Station (CRS), Veppanthattai, Perambalur districtand waterlogged soils of Agricultural Research Station (ARS), Bhavani Sagar, Erode districtand high in the acidic soils of Annaikatti, Coimbatore district. The available

Table 1: Physico-chemical properties of soils used in the experiment.

Treatments	Textural	Physical properties			Chemical properties					
	class	Sand (%)	Silt (%)	Clay (%)	pH	EC (dSm^{-1})	OC (%)	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})
T_1	Sandy clay loam	53.6	16.9	29.1	8.2	0.23	4.93	254	31.5	566
T_2	Clay	10.2	19.2	70.5	7.3	0.62	0.92	390	32.5	368
T_3	Clay loam	33.5	27.8	38.6	5.65	0.40	3.84	568	28.6	585
T_4	Sandy loam	65.0	16.8	18.2	8.5	2.4	0.46	220	16.5	324
T_5	Clay loam	38.2	15.3	46.5	7.8	0.58	0.48	210.5	12.8	418
T_6	Sandy clay loam	66.3	13.4	20.2	8.92	0.22	0.42	224	19.6	154

T_1- Sandy clay loam soils of Eastern Block 37B TNAU, Coimbatore, T_2- Heavy clay soils of Cotton Research Station (CRS), Veppanthattai, Perambalur district, T_3- Acidic soils of Annaikatti, Coimbatore district, T_4- Coastal saline soils of Cuddalore district, T_5- Waterlogged soils of Agricultural Research Station (ARS), Bhavani Sagar, Erode district, T_6- Sodic soils of ADAC and RI, Trichy district.

Table 2: Effect of problematic soil stress on germination indices of Browntop millet.

Treatments	Germination %	Germination energy %	Coefficient of velocity of germination	Germination index
T_1	90.00	82.50	80.11	29.38
T_2	72.50	67.50	74.17	23.75
T_3	70.00	70.00	72.50	23.96
T_4	50.00	47.50	64.29	16.46
T_5	17.50	15.00	38.75	5.63
T_6	15.00	12.50	35.00	4.79
Sem±	3.07	2.30	3.77	0.91
CD (P=0.05)	9.26	6.92	11.38	2.76

T_1- Sandy clay loam soils of Eastern Block 37B TNAU, Coimbatore, T_2- Heavy clay soils of Cotton Research Station (CRS), Veppanthattai, Perambalur district, T_3- Acidic soils of Annaikatti, Coimbatore district, T_4- Coastal saline soils of Cuddalore district, T_5- Waterlogged soils of Agricultural Research Station (ARS), Bhavani Sagar, Erode district, T_6- Sodic soils of ADACand RI, Trichy district.

phosphorus levels in the soils obtained from the sandy clay loam soils of Eastern Block 37B TNAU, Coimbatore, the heavy clay soils of Cotton Research Station (CRS), Veppanthattai, Perambalur districtand acidic soils of Annaikatti, Coimbatore district exhibited high levels. In contrast, the soils collected from the coastal saline soils of Cuddalore district, waterlogged soils of Agricultural Research Station (ARS), Bhavani Sagar, Erode districtand sodic soils of ADACand RI, Trichy district exhibited medium levels. All the soils used in this experiment were high in available potassium except the sodic soils collected from ADACand RI, Trichy district which is medium in level.

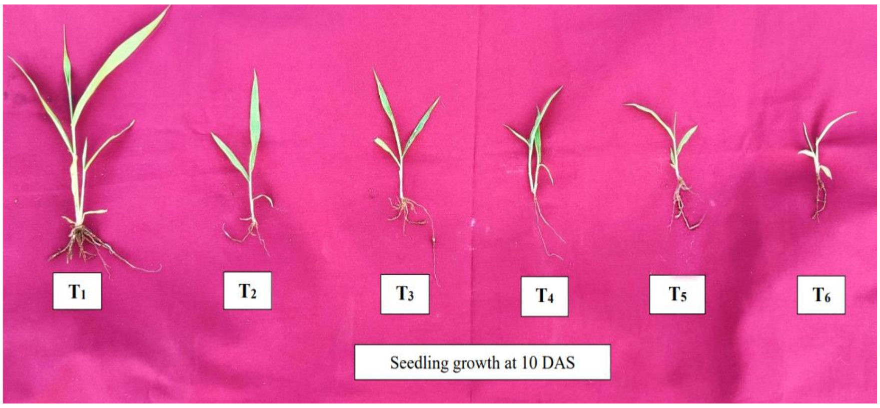
Germination and seedling growth indices

The experimental results indicated that the gemination indices (Table 2) and seedling growth (Table 3 and Fig 1) of Browntop millet were significantly affected by different problematic soils. The treatment sandy clay loam soils of Eastern Block 37B TNAU, Coimbatore (T1), recorded significantly higher germination percentage (90%), shoot length (5.15 cm), root length (4.85 cm) and seedling length (10 cm) than all the other treatments which was followed by the treatment with heavy clay soils of Cotton Research Station (CRS), Veppanthattai, Perambalur district (T2) and the acidic soils of Anaikatti, Coimbatore district (T3). The improved germination and seedling growth indices observed in the sandy clay loam soils of Eastern Block 37B TNAU, Coimbatore (T1) can be attributed to the favorable physical, chemical and biological properties of the soil, as well as the abundant supply of macro and micronutrients. These conditions positively influence cell division, enlargement and overall plant metabolism, contributing to the overall performance of the plant. Similar outcomes were noted in wheat by Khatun *et al.* (2013) when comparing control treatments with stress treatments. The lower germination percentage (15%), shoot length (2.30 cm), root length (2.90 cm)and seedling length (5.2 cm) were recorded in sodic soils of ADAC and RI, Trichy district (T6) due to the presence of high exchangeable sodium levels, poor soil structureand nutrient imbalances. Rahman *et al.,* 2022 noted that an

Table 3: Effect of problematic soil stress on seedling growth of Browntop millet.

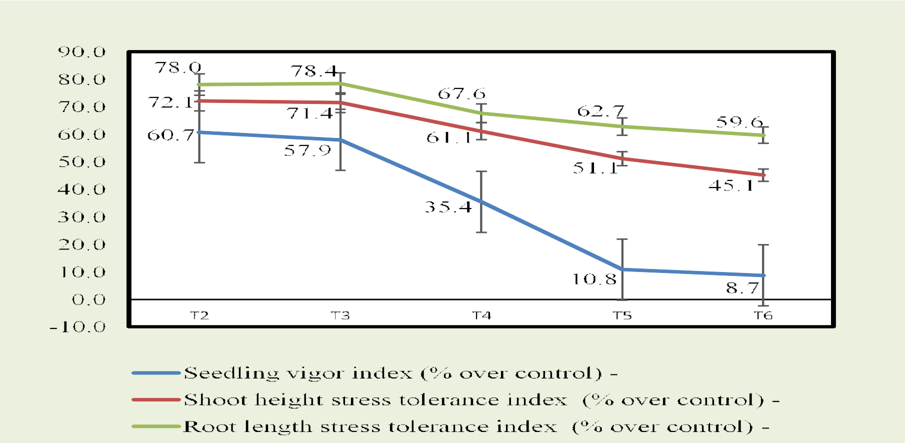
Treatments	Shoot length (cm)	Root length (cm)	Seedling length (cm)	Root: Shoot length ratio	Vigor Index
T_1	5.15	4.85	10.00	0.94	900
T_2	3.68	3.80	7.48	1.04	546
T_3	3.65	3.78	7.43	1.04	520
T_4	3.10	3.28	6.38	1.09	318
T_5	2.63	3.03	5.65	1.16	97
T_6	2.30	2.90	5.20	1.28	78
Sem±	0.19	0.23	0.30	0.07	21.72
CD (P=0.05)	0.57	0.71	0.92	0.20	65.47

T_1- Sandy clay loam soils of Eastern Block 37B TNAU, Coimbatore, T_2- Heavy clay soils of Cotton Research Station (CRS), Veppanthattai, Perambalur district, T_3- Acidic soils of Annaikatti, Coimbatore district, T_4- Coastal saline soils of Cuddalore district, T_5- Waterlogged soils of Agricultural Research Station (ARS), Bhavani Sagar, Erode district, T_6- Sodic soils of ADAC and RI, Trichy district.



T_1-Sandy clay loam soils of Eastern Block 37B TNAU, Coimbatore, T_2- Heavy clay soils of Cotton Research Station (CRS), Veppanthattai, Perambalur district , T_3-Acidic soils of Annaikatti, Coimbatore district, T_4-Coastal saline soils of Cuddalore district, T_5- Waterlogged soils of Agricultural Research Station (ARS), Bhavani Sagar, Erode district, T_6-Sodic soils of ADACand RI, Trichy district.

Fig 1: Seedling growth of Browntop millet at 10 DAS as influenced by various soil stress treatments.



T1-Sandy clay loam soils of Eastern Block 37B TNAU, Coimbatore, T2- Heavy clay soils of Cotton Research Station (CRS), Veppanthattai, Perambalur district, T3-Acidic soils of Annaikatti, Coimbatore district, T4-Coastal saline soils of Cuddalore district, T5- Waterlogged soils of Agricultural Research Station (ARS), Bhavani Sagar, Erode district, T6-Sodic soils of ADACand RI, Trichy district.

Fig 2: Effect of problematic soils on stress tolerance indices of Browntop millet.

increased sodium concentration hindered the germination process and induced toxicity during sprouting and emergence, as reported in research on Napier grass (*Pennisetum purpureum*). Similar findings were noted by Surya *et al.* (2023) under different sodicity levels in rice varieties.

Similarly, the sandy clay loam soils of Eastern Block 37B TNAU, Coimbatore (T1) recorded significantly higher germination energy (82.5%) which was followed by the treatments heavy clay soils of Cotton Research Station (CRS), Veppanthattai, Perambalur district (67.5%) and the acidic soils of Anaikatti, Coimbatore district (70%). This higher germination energy correlated with a quicker emergence of seedlings, resulting in robust and uniform plants better suited to environmental conditions. Conversely, treatments with lower germination energy (12.5%) recorded with sodic soils of ADAC and RI, Trichy district(T6) indicate reduced vitality, delayed germination, uneven crop distribution, suboptimal adaptation to environmental factorsand an overall decrease in plant performance. Likewise, the same treatment (T1) recorded a significantly higher coefficient of the velocity of germination (80.11), which was on par with the heavy clay soils of Cotton Research Station (CRS), Veppanthattai, Perambalur district (74.17) and the acidic soils of Anaikatti, Coimbatore district (72.5). As per the criteria delineated by Jones and Sanders (1987) coefficient of the velocity of germination functions as an indicator of germination speed. This metric increases with a greater number of germinated seeds and a shortened germination time. Comparable outcomes of CVG in Browntop millet were noted, consistent with the findings of Khatun *et al.,* 2013. Significantly, a higher germination index (29.38) was recorded with sandy clay loam soils of Eastern Block 37B TNAU, Coimbatore (T1) followed by the treatments with heavy clay soils of Cotton Research Station (CRS), Veppanthattai, Perambalur district (23.75) and the acidic soils of Anaikatti, Coimbatore district (23.96). Germination energy serves as a numerical gauge for evaluating the vitality and performance of seeds during the germination process. This not only signifies a larger percentage of seeds that have undergone germination but also indicates a more uniform and expedited germination process. Similar results on the germination index were reported by Mishra *et al.* (2019).

In the case of root: shoot ratio, the same treatment (T1) recorded a significantly lower value (0.95) and was on par with the heavy clay soils of Cotton Research Station (CRS), Veppanthattai, Perambalur district (1.04), acidic soils of Anaikatti, Coimbatore district (1.04) and coastal saline soils of Cuddalore district (1.09) whereas the waterlogged soils of Agricultural Research Station (ARS), Bhavani Sagar, Erode district (1.16) and sodic soils of ADAC and RI, Trichy district (1.28) recorded higher root: shoot ratio. The lower root-to-shoot ratio might indicate a plant strategy that prioritizes above-ground shoot growth over below-ground root development. This could be advantageous in situations where rapid shoot growth is essential, such as in competitive environments for sunlight. Similar observations were reported by Khatun *et al.* (2013). A higher seedling vigor index (SVI) was recorded with sandy clay loam soils of Eastern Block 37B TNAU, Coimbatore (900), which was significantly higher than all the other treatments. A higher seedling vigor index suggests more vigorous and healthier seedlings, while a lower index may indicate reduced vigor and potential challenges in seedling establishment. Similar results were documented by Mishra *et al.,* 2019 and Alam *et al.* (2023).

Stress tolerance indices

The stress tolerance indices (Fig 2) of Browntop millet in the experiment were influenced by various problematic soils. The treatment with heavy clay soils of Cotton Research Station (CRS), Veppanthattai, Perambalur district (T2) and acidic soils of Anaikatti, Coimbatore district (T3) exhibited the higher seedling vigor index (60.7 and 57.9% over control), shoot length stress tolerance index (72.1 and 71.4% over control)and root length stress tolerance index (78 and 78.4% over control), respectively. Subsequently, the treatments with coastal saline soils of Cuddalore district (T4), waterlogged soils of Agricultural Research Station (ARS), Bhavani Sagar, Erode district (T5) and sodic soils of ADAC and RI, Trichy district (T6) showed progressively lower tolerance levels. A decline in stress tolerance index values suggests that the plants may be sensitive to the specific stress conditions applied. Here the treatment T1 was taken as a control treatment for comparison of stress tolerance indices. This pattern of response is similar to findings by Ahmed *et al.* (2009) in sunflower under drought stress conditions and Chetariya *et al.* (2024) for heat tolerance in chickpea.

CONCLUSION

The present investigation concludes that problematic soils significantly influenced the germination, seedling growthand stress tolerance indices of Browntop millet. The sandy clay loam soils of Eastern Block 37B at TNAU, Coimbatore, exhibited significantly higher germination percentage, germination energy, coefficient of velocity of germination, germination index, shoot length, root lengthand vigor index which was followed by the heavy clay soils of Cotton Research Station (CRS), Veppanthattai, Perambalur district (T2) and acidic soils of Anaikatti, Coimbatore district (T3). While lower values were observed with the sodic soils of ADAC and RI, Trichy district. The research findings indicated that the germination and seedling growth of Brown top millet were markedly influenced by the soil characteristics and its fertility status.

Conflict of interest

All authors declare that they have no conflict of interest.

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