

# Effect of vermicompost and its mixtures with water treatment residuals on soil chemical properties and barley growth

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## Abstract

Water treatment residuals (WTR) and organic amendments can improve both organic wastes recycling and soil reclamation. The present work was carried out to evaluate the effect of vermicompost, when used alone or in combination with WTR at mixed ratios of 2:1 and 1:1 wet weight (Vermi: WTR), on soil chemical properties of saline sodic soils, and on barley growth (*Hordeum aestivum*). The results showed that the soil EC, SAR, Cl<sup>-</sup> and Na<sup>+</sup> decreased significantly with the application of vermicompost alone and when mixed with WTR. Organic matter, CEC and nutrients available (N, P and K) were increased as the rate of the organic materials increased. The treatment of vermicompost: WTR (2:1 wet weight ratio) at level of 10g kg<sup>-1</sup> soil gave the highest grain weight of barley plants compared to other treatments. Based on the results of the current study, the combinations of vermicompost and WTR can be considered as an ameliorating material to reclaim of salt-affected soils and to improve the yield of barley plants. Moreover, it can improve the efficiency of organic wastes and WTR disposal.

**Keywords:** Vermicompost, Amendments, Reclamation, Barley, Disposal.

## 1. Introduction

The total salt affected soil areas in the world are about 955 Mega ha (FAO, 1995), of which 0.9 Mega ha occur in Egypt. Under saline conditions, dissolved salts may accumulate in soils and inhibit plant growth. The three main problems caused by sodium-induced dispersion are reduced infiltration, reduced hydraulic conductivity, and surface crusting (Qadir and Schubert, 2002). The improvement of soil physical and chemical properties in salt-affected soils may be achieved by using good quality water, soil amendments, good drainage and appropriate cultural practices (Grattan and Oster, 2003). In this respect, the development of the most suitable reclamation technology or a combination of technologies may be critical to optimize farm management for better crop yields in salt-affected soils. Although several reclamation techniques have been researched, including physical, biological and chemical treatment, limited literature is available on the combination of vermicompost and water treatment residuals to improve salt-affected soils.

Many researchers such as (Wahdan *et al.*, 1999) used different soil conditioners (e.g. organic manures, mineral fertilizers, sulfur and gypsum) to reclaim some chemical and physical properties of different soils. Vermicomposts, which are stabilized organic materials produced by earthworms and microorganisms, have been reported to improve plant germination growth and yields in greenhouse crops (Edwards *et al.*, 2004). Vermicompost have large particulate surface areas that provide many micro sites for microbial activity, strong retention of nutrients, high nutrients content and rich microbial populations (Atiyeh *et al.*, 2000c).

Natural organic matter and suspended solids are removed from surface water for water treatments using coagulation/sedimentation by aluminium (Al) as coagulate agents (Bursill, 2001). Water treatment

residuals (WTR) are produced as a by-product of these treatments. The disposal of these by-products is a direct discharge to water bodies as disposal methods. Because of the high cost of landfill disposal, the application of WTR to agricultural land can be considered as a possible alternative. However, this has caused concerns due to their content in Al and potential contaminants, and their ability to bind phosphorus (Lombi *et al.*, 2010). Park *et al.*, (2010) reported that the WTR was likely to be used as a growth medium. It was used with rice straw compost reduce the bioavailability of heavy metals and to increase the yield of canola grown in contaminated soil (Mahmoud, 2011).

The application of WTR with compost as soil amendment improved chemicals (such as soil salinity and sodicity) and increased the yield of wheat grown on salt affected soils (Mahmoud *et al.*, 2009).

Barley plant is considered one of the most important cereal crops in Egypt. It is actually very important and can be considered as a moderate salt tolerant plant crop in arid regions, as well as in poor and saline soils (Abd El-Hady, 2007)

The objective of this study is to investigate the effect of vermicompost with and without water treatment residuals (WTR) at mixed ratios of 2:1 and 1:1 wet weight (Vermi: WTR), on the chemical properties of saline sodic soils and on the growth of barley (*Hordeum aestivum*).

## 2. Materials and methods

Composite soil samples from twenty samples were collected from the agricultural soils of Baltiem area, Kafer El-Sheikh water Governorate, Egypt. The samples taken from the upper 30 cm soil layer were air – dried, ground and sieved through 2-mm sieve to increase the uniformity of the experiment. The par-

particle size distribution of the used soil is 36.21% silt, 29.61% sand and 34.18% clay with texture grade of clay loam. Its main characteristics were 0.92% organic matter, 25.82 dS m<sup>-1</sup> EC, 42.24% ESP and 8.56 pH. Accordingly, this soil may be classified as a saline sodic soil (Brady, 1999).

### 2.1 Experiment and treatments

Barley (*Hordeum aestivum*) plants were grown in pots in a completely randomized experimental design with five replicates. Pots (35 pots) with 25 cm diameter and 35 cm depth were used in this study. Each pot was filled with 15 kg of the used fine soil and planted with (30) of barley seeds. Vermicompost (Vermi), used alone or in combination with water treatment residuals (WTR) at mixed ratios of 1:1 and 2:1 wet weight (Vermi: WTR), were added at rates of 5 and 10 g on dry weight basis per kg air-dried soil and then mixed thoroughly. The treatments used were: T0: Control; T1: 5 g of Vermicompost kg<sup>-1</sup> soil; T2: 10g of Vermicompost kg<sup>-1</sup> soil;

T3: 5g of Vermi + WTR (1:1) kg<sup>-1</sup> soil; T4: 10g of Vermi + WTR (1:1) kg<sup>-1</sup> soil; T5: 5g of Vermi + WTR (2:1) kg<sup>-1</sup> soil and T6:10g of Vermi + WTR (2:1) kg<sup>-1</sup> soil

The recommended inorganic fertilizers were added in the forms of ammonium sulfate for N, superphosphate for P and potassium sulfate for K at the rates 30 kg N, 25 kg P<sub>2</sub>O<sub>5</sub> and 50 kg K<sub>2</sub>O per fed (fed= 4200 m<sup>2</sup>), respectively. Barley plant was harvested after 12 weeks from planting. Plant organs were washed with tap water then rinsed with distilled water and dried in an oven at 60-70°C for 72 hr. The oven grain weight was recorded. After the harvesting of barely plants, the soil samples were taken from each replicate and prepared for chemical analysis.

The vermicompost used in this experiment was made of rice straw and animal wastes with local species of earthworm such as *Eisenia andrei* (Oligochaeta) and *Eisenia fetida*. Water treatment residuals (WTR) were collected from Kafer El-Dewar water treatment plant. The properties of the used soils, WTR and vermicompost are given in Table (1).

**Table 1.** Physical and chemical properties of the studied soil samples and soil amendments.

Properties	Units	Soil (n=20)	Vermicompost (n=3)	WTR (n=3)
pH		8.56	7.6	7.62
EC	dS m <sup>-1</sup>	25.82	4.65	3.23
Ca <sup>++</sup>	meq l <sup>-1</sup>	85.3	16.3	20.3
Mg <sup>++</sup>	meq l <sup>-1</sup>	70.2	12.6	5.3
Na <sup>+</sup>	meq l <sup>-1</sup>	166.5	20.3	6.3
K <sup>+</sup>	meq l <sup>-1</sup>	1.4	3.2	2.9
Al <sup>3+</sup>	mg kg <sup>-1</sup>			3315
Cl <sup>-</sup>	meq l <sup>-1</sup>	102.0	31.5	28.8
HCO <sub>3</sub> <sup>-</sup>	meq l <sup>-1</sup>	2.56	3.6	2.5
SAR		18.8	5.34	1.76
CaCO <sub>3</sub>	%	4.6		

Continued...

Properties	Units	Soil (n=20)	Vermicompost (n=3)	WTR (n=3)
OM	%	0.92	32.6	4.86
Clay	%	34.18		65.7
Total heavy metals				
Cd	mg kg <sup>-1</sup>		4.3	6.4
Zn	mg kg <sup>-1</sup>		40.6	39.7
Ni	mg kg <sup>-1</sup>		10.4	19.6
Pb	mg kg <sup>-1</sup>		19.6	43.5

Organic carbon of soils and WTR were determined according to Walkely- Black rapid titration method, as outlined by Page (1982). Based on the assumption that organic matter contains 58 % organic carbon the organic matter was calculated by multiplying the organic carbon value by the Van Bemmelen of 1.724. Whereas, the organic matter of vermicompost was calculated as the difference between ash and dry weight (50% of OM was considered organic C) (AFNOR 1991). The pH and EC were determined in extract of the saturated vermicompost, WTR and soils by means of using pH and electrical conductivity meters, respectively. The content of soluble cations (Na<sup>+</sup> Mg<sup>++</sup>, Ca<sup>++</sup>, K<sup>+</sup>) and anions (HCO<sub>3</sub><sup>-</sup> and Cl<sup>-</sup>) was determined in soil paste extract as described by Black (1982). Cationic exchange capacity (CEC) of the soils and WTR was determined by means of using sodium-ammonium acetate saturation technique (Page, 1982). The total nitrogen in raw materials was determined by Kjeldahl method (Page, 1982). Available phosphorus was extracted using NaHCO<sub>3</sub> 0.5 N and determined by using of spectrophotometer at wave length of 650 nm, as described by Black (1982). Available potassium was extracted using ammonia solution 1% and determined using flame photometer as described by Page (1982). Total heavy metals concentration was measured by atomic absorption after wet

digesting the air dried WTR and vermicompost using the mixture of concentrated H<sub>2</sub>SO<sub>4</sub> and H<sub>2</sub>O<sub>2</sub>, Black (1982). Clay of WTR and soils was measured by the international standard pipette methods using sodium hexameta-phosphate as dispersing agent according to Black (1982). Grain weight of barley plants was determined by drying in the oven at 60-70°C for 72 hours and then weighed. Treatment mean differences were statistically analyzed by the least significant difference (LSD<sub>0.05</sub>) test (SAS, 1996)

### 3. Results

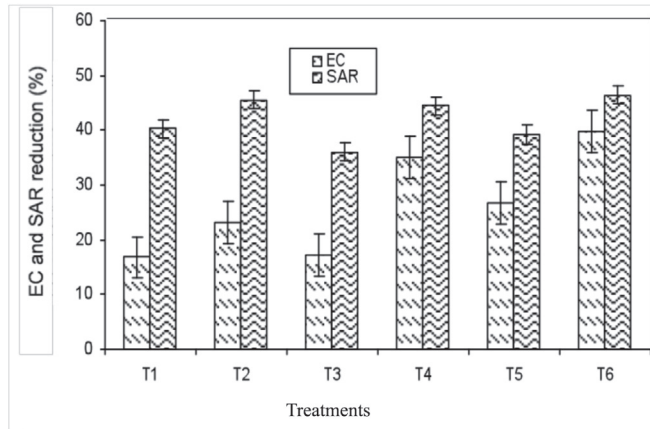
#### 3.1. Effect of vermicompost and its mixtures with WTR on the soil chemical properties

##### Salinity and sodicity

Figure 1 shows the reduction percentage of the soil salinity (EC) and sodicity (SAR) affected by the individual applications of vermicompost and in combination at different mixed ratios of WTR. With different treatments under study, the resulted reductions as a percentages (%) of EC and SAR were ranged from 16.8 and 36.0 % to 39.0 and 46.0% with the addition of vermicompost at level of 5g kg<sup>-1</sup> soil and mixed ratio of 2 : 1 (Vermi:WTR) at rate of 10g kg<sup>-1</sup> soil,

respectively. The application of vermicompost when used alone and in combination with WTR at the two mixed ratios had a significant effect on the reduction percentage of EC and SAR compared to the unamend-

ed soil. The mixture of treatments vermicompost and WTR (2:1 wet weight ratio) at level of 10g kg<sup>-1</sup> soil showed the greatest reduction in both EC and SAR compared with other treatments.



**Figure 1.** The reduction percentage of EC and SAR as affected by the application of vermicompost, and WTR/vermicompost mixture. Values are means  $\pm$  standard error ( $n=3$ ). T0: Control; T1: Vermicompost at 5 g kg<sup>-1</sup> soil; T2: Vermicompost at 10 g kg<sup>-1</sup> soil; T3: Vermi + WTR (1:1) at 5 g kg<sup>-1</sup> soil; T4: Vermi + WTR (1:1) at 10 g kg<sup>-1</sup> soil; T5: Vermi + WTR (2:1) at 5 g kg<sup>-1</sup> soil; T6: Vermi + WTR (2:1) at 10 g kg<sup>-1</sup> soil.

#### Available nitrogen, phosphorus and potassium

Application of vermicompost alone at rate of 5 and 10g kg<sup>-1</sup> soil increased significantly the NaHCO<sub>3</sub> extractable P (mg kg<sup>-1</sup>) values by 43% and 70 % over the control (Table 3), respectively. The NaHCO<sub>3</sub> extractable P did not differ significantly ( $p \leq 0.05$ ) as affected by the interaction treatments of vermicompost and WTR. Soil treated with vermicompost at rate of 10g kg<sup>-1</sup> soil had more NaHCO<sub>3</sub> extractable P than those resulted from other treatments.

The soil content (mg kg<sup>-1</sup>) of available nitrogen (N) and potassium (K) increased with individual additions of vermicompost or in combination with WTR compared to the control (Table 3). The highest content of available N and K was found in the pots treated with 10 g vermicompost kg<sup>-1</sup> soil, whereas the lowest was

recorded in the control. The available nitrogen and potassium increased with the increase of the application rates of vermicompost when used alone and in combination with WTR (Table 3). These increases were more pronounced in the pots treated with vermicompost alone than these associated the treatments of WTR and vermicompost mixtures.

#### Organic matter, CEC, pH and soluble cations and anions

The soil content (%) of organic matter and CEC was increased clearly and significantly at the level of  $p < 0.05$  followed by the soil treated by different ratios of vermicompost alone and its in combination with WTR (Table 3). Soil pH was decreased as a result of vermicompost application especially at high applica-

tion rate, whereas the interaction treatments of vermicompost and WTR effect on soil pH generally were changed slightly (Table 2).

Different applications of vermicompost when used alone or in combination with WTR reduced significantly the soil content (meq/l) of  $\text{Cl}^-$  and  $\text{Na}^+$ . The found decreases were more clear in the combination applications (Table 2). The addition of 10g vermicom-

post  $\text{kg}^{-1}$  soil at 2:1 ratio of vermicompost: WTR gave the highest reduction in the content of soluble  $\text{Cl}^-$  and  $\text{Na}^+$  followed by the treatment of 10g vermicompost  $\text{kg}^{-1}$  soil at 1:1 ratio of vermicompost: WTR. The content of soluble carbonate was similar in all treatments while the content of soluble bicarbonate was slightly increased with all treatments.

**Table 2.** Effect of vermicompost, WTR and vermicompost/WTR mixtures on salinity, soluble cations and anions in the studied soil after barley harvesting.

Treatments	pH	ECd $\text{Sm}^{-1}$	Cations		meq $^{-1}$		Anions	
			Ca $^{++}$	Mg $^{++}$	Na $^+$	K $^+$	Cl $^-$	HCO $_3^-$
Control	8.63	10.66	14.23	16.07	81.95	0.93	53.88	2.42
Vermicompost at 5 g $\text{kg}^{-1}$ soil	7.42	8.87	17.12	18.23	53.22	1.25	45.82	2.58
Vermicompost at 10 g $\text{kg}^{-1}$ soil	7.23	8.20	18.62	20.26	50.62	1.91	42.23	2.58
Vermi + WTR (1:1) at 5 g $\text{kg}^{-1}$ soil	7.83	8.82	16.73	18.21	56.43	0.99	46.62	2.38
Vermi + WTR (1:1) at 10 g $\text{kg}^{-1}$ soil	7.74	6.92	12.62	15.32	43.7	1.08	35.32	2.83
Vermi + WTR (2:1) at 5 g $\text{kg}^{-1}$ soil	7.66	7.82	14.60	16.20	50.3	1.12	38.89	2.58
Vermi + WTR (2:1) at 10 g $\text{kg}^{-1}$ soil	7.63	6.42	12.35	13.20	40.35	1.06	32.62	2.42
L.S.D at level 0.05	1.01	1.65	1.8	2.7	24.8	0.66	6.8	0.33

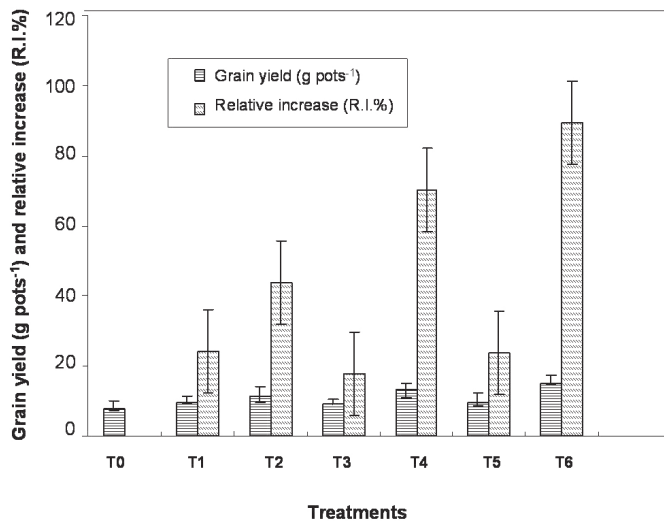
**Table 3.** Effect of vermicompost and vermicompost/WTR mixtures on CEC, OM and available P, N and K in the studied soil after barley harvesting.

Treatments	CEC C mol 100 g $^{-1}$ soil	O.M %	Available, mg $\text{kg}^{-1}$ soil		
			P	K	N
Control	32.92	0.86	30.93	35.37	635
Vermicompost at 5 g $\text{kg}^{-1}$ soil	36.19	1.52	44.32	77.37	683
Vermicompost at 10 g $\text{kg}^{-1}$ soil	37.34	1.55	52.72	92.95	687
Vermi + WTR (1:1) at 5 g $\text{kg}^{-1}$ soil	33.57	1.25	39.72	74.07	637
Vermi + WTR (1:1) at 10 g $\text{kg}^{-1}$ soil	34.66	1.43	39.89	87.27	636
Vermi + WTR (2:1) at 5 g $\text{kg}^{-1}$ soil	34.92	1.45	37.68	77.59	644
Vermi + WTR (2:1) at 10 g $\text{kg}^{-1}$ soil	35.79	1.51	39.84	83.80	636
L.S.D at level 0.05	0.59	0.32	5.78	24.0	11.0

### 3.2 Effect of vermicompost and its mixtures with WTR on grain weight of barley plants

Grain weight (g/plant) of barley plants increased significantly in soil treated by vermicompost alone or in combination with WTR at mixed ratios of 2:1 and 1:1 at both level of 5 and 10 g dry weight kg<sup>-1</sup> dry soil and vermicompost at rate of 10g kg<sup>-1</sup> soil compared with other treatments (Figure 2). High grain weight

of barley plants was obtained with the treatment of 10 g vermicompost kg<sup>-1</sup> soil mixed with WTR at ratio of 2:1 compared to other treatments. The relative increase (RI %) of grain weight of barley plants ranged from 18.0 % with the treatment of 1:1 (Vermi: WTR) ratio to 89.3% with the addition of 10g vermicompost kg<sup>-1</sup> soil at mixed ratio of 2:1 vermicompost: WTR. The relative increase of grain weight of barley plants differed significantly between the studied treatments.



**Figure 2.** Grain yield and relative increase (R.I) of barley plants as affected by the applied soil amendment levels. Values are means  $\pm$  standard error (n=3). T0: Control; T1: Vermicompost at 5 g kg<sup>-1</sup> soil; T2: Vermicompost at 10 g kg<sup>-1</sup> soil; T3: Vermi + WTR (1:1) at 5 g kg<sup>-1</sup> soil; T4: Vermi + WTR (1:1) at 10 g kg<sup>-1</sup> soil; T5: Vermi + WTR (2:1) at 5 g kg<sup>-1</sup> soil; T6: Vermi + WTR (2:1) at 10 g kg<sup>-1</sup> soil.

## 4. Discussion

### 4.1. Effect of vermicompost and its mixtures with WTR on the soil chemical properties

The SAR takes into account the adverse effect of sodium when moderated by the presence of calcium and magnesium ions. It is generally considered that a SAR value above 12 or 15 indicates that serious

soil problems will occur (i.e. permeability and tilth). This means that plants may have difficulty in absorbing water (Brady, 1999). The reduction of soil salinity and sodicity with vermicompost and its mixture with WTR may be due to vermicompost and WTR which allows continuous supply of Ca<sup>++</sup>, Mg<sup>++</sup> and other cations, in addition to Al<sup>3+</sup> which exists in the WTR. These cations lead to replace the exchangeable Na<sup>+</sup> from soil matrix and to form new stable aggregates.

These processes increase hydraulic conductivity and encourage the water to flow down and leach the salt out (Aggag and Mahmoud, 2006). The application of organic matter to salt-affected soil promotes flocculation of clay minerals, which is an essential condition for the aggregation of soil particles. It also plays an important role in increasing biopores spaces, which increase  $\text{Na}^+$  leaching. Consequently, decreased the exchangeable sodium percentage (ESP) and the electrical conductivity (Lakhdar *et al.*, 2008).

Phosphorus is one of the most essential plant nutrients. Salinity and sodicity can affect forms and dynamics of phosphorus in soil (Dominguez *et al.*, 2001). The increase of  $\text{NaHCO}_3$  - extractable P with vermicompost may be attributed to the release of humic acid during organic matter decomposition, results in a convert's unavailable soil phosphate into available forms. In addition, vermicompost is a high phosphorus content (Table 1). Marinari *et al.* (2000) found similar increases in phosphates in the soil after the application of organic amendments. The content of available P was decreased with the application of combined treatments of vermicompost and WTR compared to vermicompost alone. It is worth to mention that similar WTR contained  $3315 \text{ mg Al}^{+3}$ ,  $406 \text{ mg Ca}^{+2}$  and  $63.6 \text{ mg Mg}^{+2} \text{ kg}^{-1}$ . This indicates the presence of the inorganic components, which may precipitate the  $\text{PO}_4$  as aluminum phosphate, calcium phosphate and magnesium phosphate, respectively. During the coagulation process, alum is converted to aluminum hydroxides that are similar to aluminum hydroxides which present naturally in soils. These hydroxides can increase the soil's buffering capacity as well as the adsorption and precipitation of specific anions such as orthophosphorus (Basta *et al.*, 2001). Dempsey *et al.* (1989) reported that alum sludge had a high sportive capacity for P that reduced plant -available P and limited plant growth.

The available nitrogen (N) and potassium (K) were increased by the application of vermicompost alone or in combination with WTR which may be attributed to the vermicompost and WTR which have high N and K contents (Table 1). The addition of organic matter in the form of mulch, vermicompost and the addition of earthworm casts cause the increase of the bioavailability of these elements (Germida and Siciliano, 2000). Soil organic matter and CEC were increased with the addition of vermicompost alone or in combination with WTR to soil. These increases were attributed to high organic matter content of vermicompost and WTR (Table 1).

The increase of soluble calcium and magnesium content with the addition of vermicompost and WTR to soil is caused by high calcium and magnesium content of vermicompost and WTR (Table 1). The improvement of soil physical properties with the addition of organic matter is induced by the reduction in both  $\text{Cl}^-$  and  $\text{Na}^+$  with the leaching water (Levy, 2000).

#### 4. 2. *Effect of vermicompost and its mixtures with WTR on grain weight of barley plants*

The application of vermicomposts to soils was associated to an increase in both crop growth and yields (Kale *et al.*, 1992; Arancon *et al.*, 2004). The observed increase in grain weight of barley plants in the soil treated with vermicompost and mixtures of vermicompost and WTR coincided with EC and Na reduction and the increase of both organic matter and available nutrients. The presence of some plant growth influencing substances, such as plant growth hormones and humic acids in vermicomposts, have also been found possible to be a factor that contributes to the increase of plant growth and yields (Arancon *et al.*, 2003 a, b). In addition, with the application



of vermicompost the grain yield was increased. This increase was attributed to the improvement action of compost on the soil physical properties as well as on the nutrients status in the soil which enhances plant growth (El Sanat, 2003).

## 5. Conclusions

The results of this study have confirmed the ability of vermicompost when used alone to improve the saline-sodic soils. Moreover, when the soil is treated with mixtures of vermicompost and water treatment residuals (WTR) this gave the highest reduction in salinity, sodicity and soluble  $\text{Cl}^-$  and  $\text{Na}^+$ . Consequently, the grain weight of barley has increased. It was indicated that the application of  $10\text{g kg}^{-1}$  soil at 2:1 (Vermi: WTR) mixed ratio resulted in the best barley growth. The application of WTR with vermicompost to saline-sodic agricultural land can be used as an economic and simple alternative for disposal methods of WTR and organic wastes.

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