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RESEARCH PAPER

Effects of Deficit Irrigation on Brinjal Yield under Pot Diffuser Irrigation System

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ABSTRACT

Efficiently manage irrigation for brinjal cultivation, we explored the use of a diffuser irrigation system based on a climatological approach, particularly Evapotranspiration, for replenishing water needs. Experiment was carried out the instructional farm of the Irrigation and Drainage Engineering Department at Mahatma Phule Krishi Vidyapeeth Rahuri. The net irrigation water applied treatment (T_1) was highest i.e., 94 liters per plant. Similarly, The plant height, and yield observed superior in treatment (T_1), due to net quantity of water applied was sufficient. The efficiency of irrigation water use was at its peak in treatment T_4.

HIGHLIGHTS

- Seasonal water requirement of brinjal found highest in 100 % ETc with diffuser per plant was 94 litre/plant.
- Highest water saving registered in 40% ETc treatment was 60 %.
- 100 % ETc treatment recorded 199.54 tone ha^{-1} highest brinjal yield.
- Water use efficiency observed highest in 40 % ETc treatment was 9.03 tone ha^{-1} cm^{-1}
- Number of branches recorded highest in 100 % ETc treatment in entire growth period.
- Plant height recorded highest in 100 % ETc treatment in entire growth period.

Keywords: Pot irrigation, Diffuser, Irrigation Scheduling, Evapotranspiration, Water use efficiency

Brinjal or egg plant (*Solanum melongena* L.) belonging to the family Solanaceae is the native of India. It is one of the most popular and important vegetable grown in almost all parts of India except in higher altitudes. It is a popular vegetable with all the people and hence it is rightly called the vegetable of the masses. Brinjal has got high nutritive value, as it contains 92.70 g moisture, 1.4 g protein, 0.30 g fat, 0.30 g minerals, 0.30 g fiber, 4.0 g carbohydrates, 18.0 mg calcium, 18.0 mg oxalic acid, 47.0 mg, phosphorus, 2.0 mg potassium, 124 I U Vitamin 'A', 0.11 mg riboflavin and 12.0 mg vitamin C per 100 g of edible portion. Ravikumar *et al.* (2019). The total area under brinjal in India is 7.30 lakh ha with production 12801MT, In Maharashtra total production of brinjal is 429.91 MT which is 3.36% of total production in India (APEDA 2018). Brinjal grown on variety of soils. Deep fertile and well drained soils are suitable for it's cultivation. The average yield of brinjal is less in Maharashtra as compared to other states, because of inapplicable irrigation water scheduling and lack of knowledge of latest water management practices (Horticultural Statistics at a Glance, 2017).

The brinjal root system is characterized by a tap root. During the period before true leaves begin expansion, the primary root is penetrating into the soil and branch of roots are being formed. The major portion of the roots is concentrated in the top

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30 cm of the soil profile, but brinjal roots have been observed as deep as 1.0-1.5 m below the soil surface under field conditions. The brinjal crop has longer crop duration and hence water requirement of crop is also maximum. So the use of diffuser irrigation system for irrigation scheduling by Climatological approach such as Evapotranspiration. Water is a prime natural resource, a basic human need and precious natural asset. The average rainfall in India is 1194mm with total geographical area of 328 m ha. India is not a water rich country, so efficient utilization of available water resources is crucial for a country like India, which shares 17% of the global population and only 2.4% of land and 4% water resources (CWC Report, 2019) India has 140 million ha cultivable land in that 48.8%is irrigated area and 51.8% area depends on rain (BMEL India report, 2016) At present irrigation consumes about 84% and industrial and domestic sector consumes about 12% and 4% of total available water (CWC Report, 2019).

Combination of diffuser irrigation system with pot is a new underground irrigation technique which can be used for vegetables, fruit trees, ornamental plants etc. It is used with considering problems of water in arid and semi arid and water scares regions. It conserved water in deep soil layers. Water use efficiency can be increased by using this method of irrigation. It reduces soil and plant surface evaporation, it requires less water requirement than drip, innovative with high commercial potential, it allows injection and conservation of water in deep soil layers. So it is most effective underground irrigation system. This technique can't investigate yet so we take trial on this.

MATERIALS AND METHODS

This experiment was conducted during the summer season of 2022 on the research farm of department of irrigation and drainage Engineering, MPKV Rahuri. The soil type on experimental field is clay. The water source is open well located at near the plot. The climatic data recorded from metrological observatory of Mahatma Phule Krishi Vidyapeeth Rahuri such as maximum temperature, minimum temperature maximum relative humidity, minimum relative humidity, sunshine hours, and pan evaporation. The single diffuser or subsurface applicator was provided to each plant, to apply the water directly to root zone of brinjal. The water was applied in different irrigation quantity for each treatment, according to that observation of plant is to be recorded was presented in Table 1. In this experiment, four irrigation treatments were applied whereas, T_1 (100% ET_c with 1 Diffuser), T_2 (80% ET_c with 1 Diffuser), T_3 (60% ET_c with 1 Diffuser), and T_4 (40% ET_c with 1 Diffuser), respectively.

Details of irrigation scheduling

For the purpose of irrigation scheduling the irrigation in various treatments, predetermined soil moisture constants were used (Kharde R.P. *et. al.* 2016). Following equations were used for irrigation scheduling.

Total available water (TAW)

Total available water is the amount of water that is available for plant use. It is actually the difference of soil moistures between field capacity and permanent wilting point.

The total available water was calculated using following formulae;

$$TAW = \left[\frac{\theta_{FC} - \theta_{PWP}}{100}\right] \times \gamma \times Z_r \times 1000 \qquad \ldots(1)$$

Table 1: Observation to be recorded

Sl. No.	Particular	Frequency	Sample size	Days after sowing
(A)	**Growth studies**			
1	Plant height (cm)	4	3 plants per treatment	30, 60, 90, 120DAP
2	Number of branches	4	3 plants per treatment	30, 60, 90, 120DAP
2	Gross yield (qt ha^{-1})	—	As per treatment	At each picking
(D)	**Irrigation studies**			
1	Irrigation water applied (mm)	—	As per treatment	After completion of crop period
2	Water use efficiency (kg ha^{-1} mm)	—	As per treatment	After completion of crop period

where,

TAW = Total available water, (mm).

Θ_{FC} = Moisture content at field capacity, (%).

Θ_{PWP} = Moisture content at Permanent wilting point, (%).

γ = Bulk density, (gm/cm^3).

Z_r = Effective root zone depth, (m).

Using soil moisture constants, firstly total available water was determined for the experimental soil. For the purpose depth of effective root zone was taken 60 cm for wheat crop.

Depth of irrigation (IW)

After determining TAW, depth of irrigation was determined considering the maximum allowable depletion of 50 percent and using following equation 2.2.

$$IW = 0.50 \times TAW \qquad \ldots (2)$$

Where,

IW- Depth of irrigation to be applied in one irrigation, (mm).

Water requirement of brijal at different level of ET under pot irrigation with diffuser

The water requirement of brinjal under pot irrigation at 100 % ET_c, 80 % ET_c, 60 % ET_c, and 40 % ET_c was worked out on the basis of Crop evapotranspiration.

The crop evapotranspiration is calculated on the basis of penman monteith equation.

$$ETr = \frac{\Delta(R_n - G) + \rho_a C_p \frac{e_s - e_a}{r_a}}{\Delta + \gamma\left(1 + \frac{r_s}{r_a}\right)} \qquad \ldots(3)$$

where R_n is the net radiation, G is the soil heat flux, $(e_s - e_a)$ represents the vapour pressure deficit of the air, r_a is the mean air density at constant pressure, c_p is the specific heat of the air, D represents the slope of the saturation vapour pressure temperature relationship, g is the psychrometric constant, and r_s and r_a are the (bulk) surface and aerodynamic resistances.

Crop Evapotransipration (ET_c) – Crop evapotranspiration determined by multiplying crop coefficient to reference evapotranspiration .It is denoted by ET_c.

$$ETc = Kc \times ETr \qquad \ldots(4)$$

Where,

K_c - Crop coefficient, diemensionless.

ET_r - Reference evapotranspiration, mm

Crop area- the crop area is determined by measuring the crop canopy on 12.00 pm. The multiple reading of crop canopy diameter was taken and average reading crop canopy diameter is taken then crop area was measured by using formula;

$$Crop\ area = \frac{\pi}{4} \times d^2 \qquad \ldots(5)$$

Where, d is dia. of crop canopy, m^2

Volume of water- The volume of water was determined by multiplying the crop evapotranspiration to the crop area in litre.

$$Volume\ of\ water,\ m^3 = ETc \times Crop\ area$$

RESULTS AND DISCUSSION

An experiment was conducted on *Brinjal* to optimize the use of water in order to better productivity through different ETc approach of irrigation scheduling. The time to time observed data were analyzed and the results obtained are presented in this chapter.

Irrigation details and crop water requirement

The estimation of the water requirement of crop is one of the basic needs for crop management on the farm. Crop water requirement varies with kind of crop, degree of maturity, soil type and atmospheric conditions such as humidity, wind velocity and temperature.

1. Climatological data

The climatological data recorded at Meteorological Observatory, Department of Agronomy, MPKV, Rahuri during the period 14th December 2021 to 6th June 2022, were collected.

2. Irrigation scheduling details

Total available water (TAW) was determined using soil moisture constants of the soil. Depth of irrigation water (IW) per irrigation was calculated considering 50% maximum allowable depletion. The field capacity of soil 34%, Permanent wilting point is 17%, and bulk density of soil is 1.28 gm/cm^3

3. Amount of irrigation water applied to wheat

Details of irrigation water applied are given Irrigation water is applied through pot by pouring of water in to pot.

First common irrigation was applied in each treatment to bring the soil to field capacity. Depth of irrigation of this first common irrigation was determined on the basis of actual soil moisture content available before sowing.

After sowing daily meteorological observation was collected from Agro Meteorology Observatory of the university and reference evapotranspiration was calculated by Penmen monteith equation in PHULE JAL software. Crop evapotranspiration was calculated by multiplying reference evapotransipration (ET_r) to crop coefficient (K_c). Then total quantity water applied is calculated by mutilplying crop evapotransipration with crop area. Crop area is obtained by measuring the crop canopy. The Fig. 1 shows the field view of brinjal plot. In this plot diffuser was provided to near of the brinjal plant. The white can was placed or attached to the top of the diffuser for water storage with the capacity of 2.5 litre. The diffuser placed in the soil for direct application of water to the root zone. Later on diffuser was periodically goes down with increase in age of plant by manually.

Fig. 1: Brinjal plot with diffuser irrigation system

Table 2: Total quantity of water applied in entire growing season

Treatments	Water applied, litre	Water saving (%)
T_1 (100 % ET_c with Diffuser/ plant)	94.00	—
T_2 (80 % ET_c with Diffuser/ plant)	75.20	19.78%
T_3 (60 % ET_c with Diffuser/ plant)	56.40	40%
T_4 (40 % ET_c with Diffuser/ plant)	37.60	60%

ET_c- Crop evapotranspiration.

The Table 2 presents the outcomes of various treatments (T_1, T_2, T_3, and T_4) implemented in a specific agricultural or plant-growing scenario. Each treatment corresponds to a particular percentage of the crop Evapotranspiration (ET_c) level, utilizing a diffuser/plant system for water application. In the case of T_1, the full 100% of ET_c is provided, resulting in the application of 94.00 liters of water. Subsequently, treatments T_2, T_3, and T_4 represent 80%, 60%, and 40% of ET_c levels, respectively, resulting in water applications of 75.20, 56.40, and 37.60 liters. The table also clearly illustrates the water-saving percentage achieved by each treatment when compared to the 100% ET_c. Notably, T_2 achieves a water-saving rate of 19.78%, while T_3 conserves 40% of water, and T_4 demonstrates the highest water-saving efficiency at 60%. These results indicate that reducing the water application percentage while utilizing a diffuser per plant system can lead to substantial water conservation in agricultural practices, with T_4(40% ET_c) emerging as the most efficient approach in this regard.

Plant height (cm)

Plant height of *brinjal* crop was recorded at 30, 60, 90 DAT and at harvest. The data pertaining to mean plant height as influenced by pot irrigation at different levels of ET_c treatments (Abdalla M.M.A. *et. al.* 2018) are presented in Table 3 and graphically shown in Fig. 2.

The Table 3 provides information on plant height at different stages of growth (30 days after transplanting - 30 DAT, 60 DAT, 90 DAT, and at harvest) for four different treatments, namely. T_1, T_2, T_3, and T_4. These treatments are characterized by varying percentages of Crop Evapotranspiration (ET_c) with the application of a diffuser/plant system. Let's analyze and compare these treatments in relation to T_1 (100% ET_c with Diffuser/plant) (Ammar S. *et al*. 2020).

Table 3: Plant height (cm) as influenced by different irrigation levels

Treatments	Plant height (cm)			
	30 DAT	60 DAT	90 DAT	At harvest
T_1 (100 % ET_c with Diffuser/ plant)	41.33	60.00	86.33	91.66
T_2 (80 % ET_c with Diffuser/ plant)	36.11	53.89	76.33	82.22
T_3 (60 % ET_c with Diffuser/ plant)	31.89	44.22	63.22	69.55
T_4 (40 % ET_c with Diffuser/ plant)	29.78	39.22	53.77	68.66
F – test	Sig.	Sig.	Sig.	Sig.
SE (m) ±	0.473	1.024	1.002	0.65
CD at 5%	1.624	3.548	3.47	2.277

DAT- Day after transplanting, ET_c- Crop evapotranspiration.

At 30 DAT, all treatments (T_2, T_3, and T_4) show slightly shorter plant heights compared to T_1. T_2 has the lowest plant height at this stage, suggesting that reduced water application (80% ET_c) may lead to slower initial growth.

At 60 DAT, the trend continues, with T_2, T_3, and T_4 having shorter plant heights compared to T_1. This indicates that reducing water application impacts plant growth at this mid-stage of development.

At 90 DAT, T_1 has the tallest plants, followed by T_2, T_3, and T_4 in decreasing order. The differences in plant heights are more pronounced at this stage, suggesting that higher water application (100% ET_c) benefits plant growth.

At harvest, T_1 maintains the tallest plants, with T_2, T_3, and T_4 showing progressively shorter heights. T4, which receives only 40% ET_c, exhibits the shortest plants at harvest.

In summary, when compared to T_1 (100% ET_c with Diffuser/plant), the treatments with reduced water application (T_2, T_3, and T_4) generally result in shorter plant heights at all growth stages, with the differences becoming more pronounced as the plants mature. This indicates that reducing water application, even with the use of a diffuser/plant system, has a noticeable impact on plant growth and may lead to smaller plants at harvest. However, it's worth noting that T_4, with the lowest water application (40% ET_c), shows the greatest reduction in plant height, highlighting the significant influence of water availability on plant growth. Plant height for various treatment shows graphically at different growth stage in fig No.2.

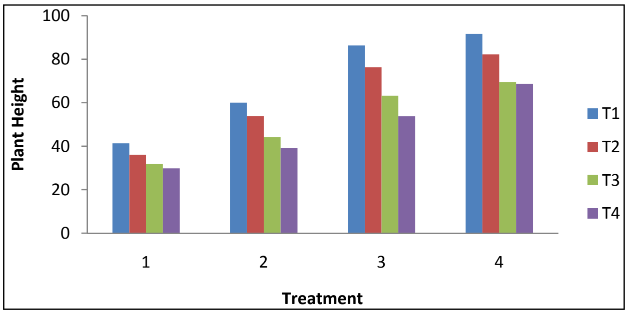

Fig. 2: Plant height at different irrigation level

Branches

In Table 4, the study recorded the number of branches at four distinct stages: 30 days after planting (DAT), 60 DAT, 90 DAT, and at the time of harvest. These observations aimed to assess how pot irrigation, applied at various levels of ET_c (Crop Evapotranspiration) treatments, impacted the number of branches in the plants under investigation (Abdalla M.M.A. *et. al.* 2018).

Table 4: No. of Branches as influenced by different irrigation levels

Treatments	Branches			
	30 DAT	60 DAT	90 DAT	At harvest
T_1 (100 % ET_c with Diffuser/ plant)	7.33	12.00	13.00	13.00
T_2 (80 % ET_c with Diffuser/ plant)	6.67	11.00	11.33	11.33
T_3 (60 % ET_c with Diffuser/ plant)	5.00	10.00	10.33	10.33
T_4 (40 % ET_c with Diffuser/ plant)	4.00	9.33	9.67	9.67
F – test	Sig.	Sig.	Sig.	Sig.
SE (m) ±	0.3191	0.1667	0.2152	0.5182
CD at 5%	1.1044	0.5767	0.7446	1.7932

DAT- Day after transplanting, ET_c- Crop evapotranspiration.

This data collection serves as a crucial component of the study's effort to understand the relationship between irrigation methods and plant branching, shedding light on the potential influence of irrigation practices on the plant's growth and development.

The Table 4 presents the data for different treatments (T_1, T_2, T_3, and T_4) applied in brinjal crop at various stages of crop growth: 30 days after transplanting (DAT), 60 DAT, 90 DAT, and at the time of harvest. These treatments involve the use of a diffuser/plant system and correspond to different percentages of the crop Evapotranspiration (ET_c) (Ammar S.*et. al*.2020). For T_1, which represents 100% of ET_c with the diffuser/plant system, the numbers of branches per plant were 7.33 at 30 DAT, 12.00 at 60 DAT, 13.00 at 90 DAT, and remained at 13.00 at harvest. In the case of T_2, which involves 80% of ET_c with the diffuser/plant system, the numbers of branches per plant were 6.67 at 30 DAT, 11.00 at 60 DAT, 11.33 at 90 DAT, and 11.33 at harvest. T_3, representing 60% of ET_c with the diffuser/plant system, resulted in 5.00 branches per plant at 30 DAT, 10.00 at 60 DAT, 10.33 at 90 DAT, and 10.33 at harvest. Lastly, T_4, which corresponds to 40% of ET_c with the diffuser/plant system, yielded 4.00 branches per plant at 30 DAT, 9.33 at 60 DAT, 9.67 at 90 DAT, and 9.67 at harvest. These results provide valuable insights into the impact of different water treatments on branch development at various stages of crop growth, highlighting the reducing the water application percentage can influence brinjal crop growth. The number of branches of brinjal at different stages showed graphically in Fig. 3.

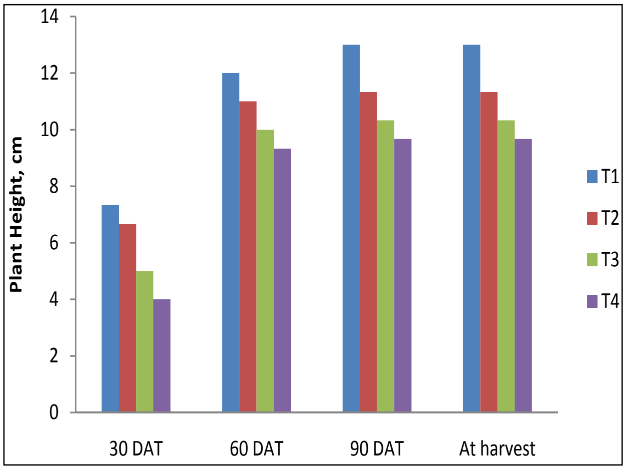

Fig. 3: Number of branches at different irrigation level

Brinjal Yield

The data pertaining in Table 5 shows that total harvested yield of brinjal throughout growing season. The maximum yield is getting in treatment T_1 other treatments T_2, T_3, T_4 are followed by T_1.

Table 5: Brinjal yield influenced by different irrigation treatment

Treatments	Brinjal Yield (tone/ha)
T_1 (100 % ET_c with Diffuser/ plant)	199.54
T_2 (80 % ET_c with Diffuser/ plant)	147.06
T_3 (60 % ET_c with Diffuser/ plant)	116.73
T_4 (40 % ET_c with Diffuser/ plant)	80.80
F – test	Sig.
SE (m) ±	8.9995
CD at 5%	31.1425

ET_c- Crop evapotranspiration.

The Table 5 presents data on the brinjal yield (tons per hectare) for different treatments, specifically T_1, T_2, T_3, and T_4. (Serhat A. 2017 and Rakha M.K.A. 2014) These treatments are characterized by varying percentages of crop Evapotranspiration (ET_c) with the application of a diffuser/plant system. To understand the results better, let's compare these treatments to the yield of T_1 (100% ET_c with Diffuser/ plant). In T_1, which represents with 100% ET_c, the brinjal yield is the highest at 199.54 tons per hectare. This indicates that when brinjal plants receive the full recommended amount of water and nutrients (100% ET_c), they produce the maximum yield.

As we move to the other treatments (T_2, T_3, and T_4) with reduced percentages of ET_c, we observe a consistent decrease in brinjal yield. T_2, which receives 80% ET_c, yields 147.06 tons per hectare, signifying a reduction in yield compared to T_1. This reduction becomes more significant as we move to T_3 (60% ET_c) with a yield of 116.73 tons per hectare and T_4 (40% ET_c) with the lowest yield of 80.80 tons per hectare.

These results suggest that reducing water application, even with the use of a diffuser/plant system, negatively impacts brinjal yield. T_1, which receives the full ET_c requirement, maximizes the yield, while decreasing water availability in T_2, T_3, and T_4 leads to progressively lower yields(Ammar S. *et al*. 2020). Therefore, it is evident that providing plants with the recommended amount of water (100% ET_c) is crucial for achieving the highest brinjal yield in this context.

Water Use efficiency

Water use efficiency is ratio of yield to water requirement. Water use efficiency shown in Table 6.

Table 6: Water use efficiency influenced by different irrigation treatments

Treatment	Water use efficiency (tone/ha-cm)
T_1 (100 % ET_c with Diffuser/ plant)	7.85
T_2 (80 % ET_c with Diffuser/ plant)	8.21
T_3 (60 % ET_c with Diffuser/ plant)	8.69
T_4 (40 % ET_c with Diffuser/ plant)	9.03

Table 6 displays water use efficiency (tons per hectare per centimeter) for different treatments, namely T_1, T_2, T_3, and T_4 (Chandan M. and Nabanita, 2019). Water use efficiency is a critical metric in agriculture as it quantifies how effectively water resources are utilized to produce a given yield. Among the treatments, T_4 demonstrates the highest water use efficiency at 9.03 tons per hectare per centimeter of water. This indicates that for every centimeter of water applied in T_4, the brinjal yield is maximized, making it the most efficient treatment in terms of water utilization. Following closely, T_3 also exhibits a strong water use efficiency of 8.69 tons per hectare per centimeter of water, indicating that it efficiently converts applied water into brinjal yield. T_2 has a slightly lower water use efficiency of 8.21 tons per hectare per centimeter of water, while T_1, which received the full recommended amount of water, has the lowest water use efficiency at 7.85 tons per hectare per centimeter of water.

In summary, these results highlight that reducing water application in treatments T_2, T_3, and T_4 improves water use efficiency, with T_4 being the most efficient in converting applied water into brinjal yield. This suggests that optimizing water usage while maintaining crop yield is a key consideration in sustainable agriculture, and treatments like T_4 demonstrate effective water management practices.

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CONCLUSION

The net irrigation water requirement for brinjal varied across different treatments. Under pot irrigation, it was found to be 94 liters per plant for 100% ET_c, 56.40 liters per plant for 80% ET with a diffuser, 56.40 liters per plant for 60% ET_c with a diffuser, and 37.60 liters per plant for 40% ET_c with a diffuser. When comparing water savings of pot irrigation at 80% ET_c, 60% ET_c, and 40% ET_c with 100% ET_c pot irrigation, there were savings of 19.78%, 40%, and 60%, respectively. Plant height showed variations among treatments, with the highest height observed in pot irrigation at 100% ET_c with a diffuser, followed by 80% ET_c with a diffuser, 60% ET_c with a diffuser, and 40% ET_c with a diffuser. Brinjal yield was highest in T_1 (100% ET_c with a diffuser) at 199.54 t/ha and lowest in T_4 (40% ET_c with a diffuser) at 80.80 t/ha, representing a 60% water saving. Notably, irrigation water use efficiency was highest in T_4 (9.03 tons/ha-cm), followed by T_3 (8.69 tons/ha-cm), T_2 (8.21 tons/ha-cm), and T_1 (7.85 tons/ha-cm). It's worth mentioning that pot irrigation at 100% water requirement with a diffuser significantly increased green brinjal yield, albeit without any water savings. These findings emphasize the importance of optimizing irrigation practices to achieve higher crop yields and water use efficiency, with variations observed across different treatments.

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