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Management of grape anthracnose under field condition

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Abstract
Grape (*Vitis vinifera* L.) is an important commercial fruit crop worldwide, however, its productivity and fruit quality are severely constrained by fungal diseases such as downy mildew (*Plasmopara viticola*), powdery mildew (*Erysiphe necator*), anthracnose (*Colletotrichum gloeosporioides*) and Botrytis bunch rot (*Botrytis cinerea*). Among these, anthracnose caused by *Colletotrichum gloeosporioides* popularly known as Bird's Eye Spot is highly destructive, particularly in tropical and subtropical regions. The present study conducted on the management of grape anthracnose under field conditions during back pruning (April) and fore pruning (October). Among the treatments tested, fluopyram 17.7% + tebuconazole 17.7% SC (T_{11}) consistently recorded the lowest disease severity of 24.63 with highest reduction over control of 51.84 percent during back pruning (April). During fore pruning (October), fluopyram 17.7% + tebuconazole 17.7% SC (T_{11}) recorded the lowest disease severity of 12.71 PDI and highest reduction over control of 53.15 percent. Which followed by copper sulphate 47.15% + mancozeb 30% WG (T_{10}) (26.25 to 13.55% PDI). Other effective fungicides included tebuconazole 25.9% EC (T_8) (27.42 to 13.96% PDI) and thiophanate methyl 70% WP (T_6) (27.83 to 14.48% PDI), while mancozeb 75% WP (24.63 to 12.71% PDI) was least effective. The untreated control exhibited the highest disease severity (37.95 to 17.95% PDI). Maximum grape yield was recorded with T_{11} (30.75 t/ha), followed by T_{10} (29.85 t/ha) and T_8 (29.00 t/ha), fluopyram 17.7% + tebuconazole 17.7% SC at 0.6 ml/L and copper sulphate 47.15% + mancozeb 30% WG at 2.0 g/L treatments achieved the highest economic returns with a B:C ratio of 3.33. Overall, treated plots significantly reduced disease severity and improved yield and profitability compared to the untreated control.

Keywords: Benefit cost ratio, *Colletotrichum gloeosporioides*, fungicides, grape anthracnose, management

1. Introduction
Grapes are originally a temperate fruit, have successfully adapted to subtropical and tropical regions. They are nutritionally rich, containing sugars, organic acids (tartaric and malic), vitamins (B_1 and B_2), minerals (calcium, phosphorus and iron) and anthocyanidin pigments. Grapes are utilized for multiple purposes, including fresh consumption, raisin production, juice extraction and winemaking (Radha and Mathew, 2007) [15]. Globally, grape cultivation covers about 7.1 million hectares, producing approximately 77.7 million tonnes with an average productivity of 10.9 t/ha (2024). The leading producers include China, Italy, France, Spain, the USA, Turkey, and India (Anon., 2025) [5]. In India, table grape production primarily depends on varieties such as 'Thompson Seedless' and 'Sharad Seedless'. Around 85 percent of the total 179.63 thousand hectares of grape area in the country is located in tropical regions, producing about 3,904.29 thousand tonnes with an average productivity of 21.74 t/ha. Major grape-growing states include Maharashtra, Karnataka, Telangana and Tamil Nadu. Among these, Karnataka stands out with a production of 1,224.67 thousand tonnes from 47.12 thousand hectares, achieving an impressive productivity of 25.99 t/ha (Anon., 2024) [4].
The main losses due to insect pests and diseases are high and for their management many sprays of several pesticides are required which accounts to 30 percent of the total cost of production. Among the diseases appearing on grapes, fungal diseases are the most destructive followed by a few bacterial, virus and nematode infestation of minor importance.

Some of the important diseases affecting grapes in India are powdery mildew (*Uncinula necator*), downy mildew (*Plasmopara viticola*), leaf spot (*Cercospora viticola*), black spot (*Guignarddia bidwilli*), coniothyrium blight (*Coniothyrium diplodiella*), foot rot (*Rhizoctonia solani*, *Fusarium* and *Alternaria* species), rust of vine (*Phakospora vitis*), drying of grape (*Hendersonula toruloidea*), blight disease (*Alternaria vitis*), leaf spot (*Drechslera rostrata*), Anthranose (*Elsinoe ampelina*), dead arm of grapes (*Phomopsis viticola*), Bacterial leaf spot (*Xanthomonas campestris*) (Pathak, 1980) [14]. However, in the warm, tropical and sub-tropical environment, anthracnose disease was caused by *Colletotrichum gloeosporioides* (Sawant *et al.*, 2012) [17]. The anthracnose of grapes, commonly called "Bird's Eye Spot," is a major grape disease after downy and powdery mildew. First mentioned by Pliny in first century Italy and scientifically reported by Burrill (1886) [7] in the U.S., it likely spread from Europe through imported vines. In India, it was first recorded near Pune in 1903 (Butler, 1905) [8] and later reported in Madras (Chennai), Mysore, Uttar Pradesh and Kashmir. Today, it occurs in all major grape-growing states, including Maharashtra, Karnataka, Punjab, Haryana, Andhra Pradesh, Uttar Pradesh, and Tamil Nadu. Native to Europe, the disease primarily attacks young leaves, tendrils and berries, causing leaf fall, stunted growth, reduced yield and economic losses worldwide (Agrios, 2005; Thind *et al.*, 2004; Sompong *et al.*, 2012) [1, 20, 19]. Globally, anthracnose has caused severe crop losses: 83-100 percent in Chile (Anderson, 1956) [3], up to 80 percent in Russia (Winkler, 1965), and 18.5 percent in China (He, 1999) [11]. In India, recurring outbreaks reduce yield and vine health. Losses of 15-20 percent were reported in Punjab and Haryana (Bedi *et al.*, 1969) [6], 10-46.5 percent reduction in Punjab (Jindal and Bhavani, 2002) [13] and 15-30 percent in Maharashtra (Deshmukh, 2006) [10] and Karnataka consistently showed significant productivity reductions (Jamadar and Lingaraju, 2011) [12]. There is lot of information available on chemical control of anthracnose of grape in field trials. However, it is essential to verify the efficacy of existing and new chemicals and provide *in vivo* schedule of different non-systemic and systemic fungicides that are recently developed for the effective management and recommendation to the growers of this region.

2. Material and Methods

The field experiment for the management of grape anthracnose caused by *Colletotrichum gloeosporioides* through fungicides was conducted during the cropping season of 2024-2025 at the Horticultural Farm, UAS, Raichur, on the variety Thompson Seedless. The back pruning was carried out on 15th April 2024 and fore pruning on 19th October 2024. The experiment was laid out in a randomized block design (RBD) with eleven fungicidal treatments and one untreated control, each replicated three times. The fungicides those recommended by NRC Grapes were selected for field evaluation. The fungicidal treatments comprised systemic, contact and combi fungicides applied as foliar sprays at weekly intervals. All fungicide applications were carried out using a knapsack sprayer to ensure thorough and uniform coverage of the grapevine foliage. Disease observations were recorded periodically to evaluate the efficacy of the treatments in reducing anthracnose severity under field conditions and data obtained was statistically analysed. The details of the treatments are listed below:

Details of the field experiment

Sl. No.	Particulars	
1	Location	Grape orchard, MARS, Raichur
2	Variety	Thompson Seedless
3	Spacing	3 m x 1.5 m
4	Treatments	12
5	No of plants per treatment	02
6	Replication	03
7	Date of planting	24.10.2016
8	Root Stock	Dogridge
9	No. of sprays and interval	4 sprays at weekly interval

Disease severity was scored using 0-4 scale given by Chatta (1992) [9].

Category	Numerical value	Description
I	0	Healthy foliage or leaf spots in traces
II	1	Up to 10 percent leaf area covered with anthracnose lesions
III	2	10.1-25 percent leaf area covered with slight twig infection *i.e.*, 1-3 cankers per twig
IV	3	25.1-50 percent leaf area covered with heavy twig infection *i.e.*, 4-10 cankers per twig
V	4	Above 50 percent leaf area covered with very heavy twig infection *i.e.*, above 10 cankers per twig and heavy berry infection

The percent disease index (PDI) was calculated by using following formula proposed by Wheeler (1969) [21].

$$\text{Per cent disease index} = \frac{\text{Sum of the individual disease ratings}}{\text{Number of leaves observed}} \times \frac{100}{\text{Maximum disease grade}}$$

The percent disease control over untreated control calculated using below formula

$$\text{Per cent disease control (PDC)} = \frac{\text{PDI in control (PDIC) - PDI in treatment (PDIT)}}{\text{PDI in control (PDIC)}} \times 100$$

3. Results and Discussion

Field evaluation of chemical fungicides for managing grape anthracnose during the back pruning showed that disease severity before the first spray ranged from 13.13 to 13.75 percent, with no significant differences among treatments. Following the first fungicidal application, all treatments significantly reduced disease severity compared to the untreated control with the percent disease index (PDI) ranging from 15.75 to 18.73 percent. Among the treatments, foliar application of fluopyram 17.7% + tebuconazole 17.7% SC (T_{11}) recorded the lowest disease severity of 15.75 percent, followed closely by copper sulphate 47.15% + mancozeb 30% WG (T_{10}) with 16.25 percent, indicating superior efficacy. The least effective fungicide was mancozeb 75% WP (T_3), which recorded higher disease severity (18.73% after first spray) and lower percent reduction over control. After subsequent sprays, the trend remained consistent, with fluopyram 17.7% + tebuconazole 17.7% SC (T_{11}) maintaining the minimum anthracnose severity of 24.63 percent after the fourth spray resulting in the highest percent reduction over control (51.84%), followed by T_{10} (26.25 PDI, 48.66% reduction). Other effective treatments included tebuconazole 25.9% EC (T_8) and thiophanate methyl 70% WP (T_6) which recorded 46.37 and 45.58 percent reduction over control, respectively. The untreated control consistently exhibited the highest disease severity, reaching 51.13 percent after the fourth spray (Table 1 and Fig. 1). These results demonstrate that chemical fungicides, particularly combination fungicides such as fluopyram 17.7% + tebuconazole 17.7% and copper sulphate 47.15% + mancozeb 30% are highly effective in managing grape anthracnose.

During the fore pruning season, the management of grape anthracnose using chemical fungicides revealed that disease severity before the first spray ranged from 10.25 to 10.88 percent and was statistically at par among treatments. After the first spray, all fungicides significantly reduced disease severity compared to the untreated control (15.63%), with PDI values ranging from 11.28 to 13.92 percent. Among them, fluopyram 17.7% + tebuconazole 17.7% SC (T_{11}) recorded the lowest disease severity (11.28%) followed by copper sulphate 47.15% + mancozeb 30% WG (T_{10}) (11.42%) and tebuconazole 25.9% EC (T_8) (11.85%) which were statistically at par with each other, while mancozeb 75% WP (T_3) was the least effective (13.92%). A similar trend continued in subsequent sprays, with fluopyram 17.7% + tebuconazole 17.7% SC (T_{11}) consistently maintaining minimum severity, reaching 12.71 percent after the fourth spray, corresponding to the highest percent reduction over control (53.15%), followed by T_{10} (13.55 PDI, 50.06%) and T_8 (13.96 PDI, 48.54%), all significantly superior to the other fungicides. Treatments with thiophanate methyl 70% WP (T_6), hexaconazole 5% EC (T_7) and propineb 70% WP (T_1) were moderately effective with disease severity of 14.48, 15.12 and 16.15 percent, respectively, after the fourth spray, while the untreated control recorded the highest disease severity (27.13%).

Analysis of grape yield across different treatments showed that all fungicidal applications were significantly superior to the untreated control. The highest yield was recorded with fluopyram 17.7% + tebuconazole 17.7% SC at 0.6 ml/L (T_{11}), producing 30.75 t/ha, followed by copper sulphate 47.15% + mancozeb 30% WG at 2 g/L (T_{10}) with 29.82 t/ha, these two treatments were statistically at par. This was followed by tebuconazole 25.9% EC at 1 ml/L (T_8), which recorded 29.00 t/ha and was at par with thiophanate methyl 70% WP at 1 g/L (T_6) and hexaconazole 5% EC at 2 ml/L (T_7), which produced yields of 28.73 t/ha and 27.90 t/ha, respectively. The untreated control recorded the lowest yield, producing 16.31 t/ha (Table 2 and Fig. 2).

The benefit-cost ratio (B:C) of the treatments ranged from 1.88 to 3.33. Among the fungicide treatments evaluated, fluopyram 17.7% + tebuconazole 17.7% SC at 0.6 ml/L and copper sulphate 47.15% + mancozeb 30% WG at 2.0 g/L recorded the highest net returns and B:C ratios (3.33 each), indicating superior economic efficiency and yield enhancement per unit investment compared to other treatments. Other fungicides, such as tebuconazole 25.9% EC at 1 ml/L and hexaconazole 5% EC at 2 ml/L, also exhibited high profitability with B:C ratios of 3.18 and 3.14, respectively. In contrast, the untreated control showed markedly lower net benefits and cost-effectiveness (Table 3).

In the field conditions, the combi fungicide fluopyram 17.7% + tebuconazole 17.7% SC (T_{11}) consistently performed best in reducing anthracnose severity, might be due to its dual mode of action with both systemic and protective properties that ensured long lasting effectiveness under vineyard conditions. Similarly, copper sulphate 47.15% + mancozeb 30% WG (T_{10}) also showed high efficacy, which might be attributed to its multi-site action. In both back pruning and fore pruning seasons, these two fungicides maintained superior performance compared to other treatments, thereby providing reliable management of anthracnose and contributing to improved grape yield. Similarly, field experiment conducted by Sharma *et al.* (2022) [18] reported that application of fluopyram + tebuconazole (125+125 g a.i./ha) recorded the lowest terminal disease severity 14.07 percent anthracnose and 11.51 percent angular leaf spot with reduced AUDPC and infection rate. This treatment also resulted in the highest yield increase of 42.37 percent (2014) and 33.11 percent (2015) over control. Saha *et al.* (2016) [16] field studies conducted field studies during the 2009-10 and 2010-11 seasons showed that the combination fungicide fluopyram 20% + tebuconazole 20% SC at 250 g ha^{-1} provided the highest disease control, with 68.12 percent and 68.69 percent reduction in anthracnose and corresponding PDI values of 14.6 and 15.4, respectively. Similarly, under field conditions, fluopyram + tebuconazole significantly reduced anthracnose severity to 5.3 percent on nursery plants and 6.5 percent on mature grapevines, compared to 90 and 48 percent in the untreated control (Amarjit *et al.*, 2011) [2].

Table 1: Management of grape anthracnose during the back pruning 2024

Tr. No.	Treatment	Percent disease index					Percent reduction over control
		Before 1st spray	After 1st spray	After 2nd spray	After 3rd spray	After 4th spray	
T_1	Propineb 70% WP @ 3 g/L	13.25 (21.35) *	17.88 (25.01)	21.13 (27.36)	26.50 (30.98)	31.15 (33.93)	39.08
T_2	Chlorothalonil 75% WP @ 2 g/L	13.50 (21.56)	17.63 (24.82)	20.85 (27.17)	26.15 (30.76)	30.48 (33.51)	40.40
T_3	Mancozeb 75% WP @ 2 g/L	13.75 (21.77)	18.73 (25.64)	22.79 (28.51)	28.33 (32.16)	37.95 (38.03)	25.78
T_4	Zineb 75% WP @ 2 g/L	13.63 (21.67)	18.50 (25.47)	22.43 (28.27)	28.00 (31.95)	33.10 (35.12)	35.26
T_5	Carbendazim 50% WP @ 1 g/L	13.33 (21.41)	18.25 (25.29)	21.88 (27.89)	27.25 (31.47)	31.73 (34.28)	37.95
T_6	Thiophanate methyl 70% WP @ 1 g/L	13.63 (21.67)	16.93 (24.62)	19.75 (26.74)	24.63 (30.23)	27.83 (32.38)	45.58
T_7	Hexaconazole 5% EC @ 2 ml/L	13.50 (21.56)	17.35 (24.62)	20.25 (26.74)	25.35 (30.23)	28.68 (32.38)	43.91
T_8	Tebuconazole 25.9% EC @ 1 ml/L	13.63 (21.67)	16.63 (24.06)	19.33 (26.08)	24.25 (29.50)	27.42 (31.58)	46.37
T_9	Carbendazim 12% + Mancozeb 63% WP @ 2 g/L	13.28 (21.37)	18.15 (24.06)	21.65 (26.08)	27.00 (29.50)	31.25 (31.58)	38.88
T_{10}	Copper Sulphate 47.15% + Mancozeb 30% WG @ 2 g/L	13.50 (21.56)	16.25 (23.77)	18.85 (25.73)	23.43 (28.95)	26.25 (30.82)	48.66
T_{11}	Fluopyram 17.7% + Tebuconazole 17.7% SC @ 0.6 ml/L	13.13 (21.24)	15.75 (23.38)	18.33 (25.35)	22.05 (28.01)	24.63 (29.75)	51.84
T_{12}	Control (untreated)	13.63 (21.67)	20.25 (26.74)	26.25 (30.82)	37.63 (37.84)	51.13 (45.65)	—
S. Em. ±		0.187	0.247	0.295	0.376	0.457	—
C. D. at 5 %		NS	0.729	0.872	1.11	1.348	—

*Figures in parenthesis are arc sine transformed values Observations were recorded at 7 days after each spray

Table 2: Management of grape anthracnose during the fore pruning 2024-25

Tr. No.	Treatment	Percent disease index					Percent reduction over control	Yield (t/ha)
		Before 1st spray	After 1st spray	After 2nd spray	After 3rd spray	After 4th spray		
T_1	Propineb 70% WP @ 3 g/L	10.33 (18.75) *	13.42 (21.49)	14.55 (22.42)	15.45 (23.15)	16.15 (23.70)	40.47	27.23
T_2	Chlorothalonil 75% WP @ 2 g/L	10.25 (18.67)	13.32 (21.41)	14.40 (22.30)	15.25 (22.99)	15.76 (23.39)	41.91	27.50
T_3	Mancozeb 75% WP @ 2 g/L	10.88 (19.26)	13.92 (21.91)	15.12 (22.88)	16.75 (24.16)	17.95 (25.07)	33.84	24.90
T_4	Zineb 75% WP @ 2 g/L	10.50 (18.91)	13.65 (21.68)	14.85 (22.67)	15.95 (23.54)	17.12 (24.44)	36.90	25.65
T_5	Carbendazim 50% WP @ 1 g/L	10.63 (19.03)	12.88 (21.03)	13.82 (21.82)	15.20 (22.95)	16.58 (24.03)	38.89	26.28
T_6	Thiophanate methyl 70% WP @ 1 g/L	10.25 (18.67)	12.42 (20.64)	13.15 (21.26)	14.05 (22.01)	14.48 (22.37)	46.63	28.73
T_7	Hexaconazole 5% EC @ 2 ml/L	10.33 (18.75)	12.05 (20.31)	12.92 (21.07)	13.88 (21.87)	15.21 (22.95)	43.94	27.90
T_8	Tebuconazole 25.9% EC @ 1 ml/L	10.43 (18.84)	11.85 (20.14)	12.65 (20.83)	13.35 (21.43)	13.96 (21.94)	48.54	29.00
T_9	Carbendazim 12% + Mancozeb 63% WP @ 2 g/L	10.63 (19.03)	12.25 (20.49)	13.28 (21.37)	14.58 (22.18)	16.38 (23.87)	39.62	26.68
T_{10}	Copper Sulphate 47.15% + Mancozeb 30% @ WG 2 g/L	10.25 (18.67)	11.42 (19.75)	12.18 (20.43)	13.05 (21.18)	13.55 (21.60)	50.06	29.82
T_{11}	Fluopyram 17.7% + Tebuconazole 17.7% SC @ 0.6 ml/L	10.35 (18.77)	11.28 (19.62)	12.05 (20.31)	12.50 (20.70)	12.71 (20.89)	53.15	30.75
T_{12}	Control (untreated)	10.63 (19.03)	15.63 (23.29)	18.73 (25.64)	22.50 (28.32)	27.13 (31.39)	—	16.31
S. Em. ±		0.144	0.185	0.201	0.219	0.237	—	0.384
C. D. at 5 %		NS	0.545	0.593	0.645	0.698	—	1.135

*Figures in parenthesis are arc sine transformed values Observations were recorded at 7 days after each spray

Table 3: Economics for the management of grape anthracnose during 2024-25

Tr. No.	Treatment Details	Formulation dose (g or ml/ha)	Cost of inputs (cost of fungicides+ cost of labour)/ha	Total Yield (q/ha)	Total income (Rs/ha)	Total cost of cultivation (Avg. cost of cultivation + cost of input) (Rs./ha)	Net benefit (Rs/ha)	B:C
T_1	Propineb 70% WP @ 3 g/L	1500	21920	27.23	816900	318105	498795	3.00
T_2	Chlorothalonil 75% WP @ 2 g/L	1000	25032	27.50	825000	321217	503783	3.00
T_3	Mancozeb 75% WP @ 2 g/L	1000	13600	24.90	747000	309785	437215	2.81
T_4	Zineb 75% WP @ 2 g/L	1000	16000	25.65	769500	312185	457315	2.88
T_5	Carbendazim 50% WP @ 1 g/L	500	14000	26.28	788400	310185	478215	2.97
T_6	Thiophanate methyl 70% WP @ 1 g/L	500	14000	28.73	771900	310185	461715	2.90
T_7	Hexaconazole 5% EC @ 2 ml/L	1000	14880	27.90	837000	311065	525935	3.14
T_8	Tebuconazole 25.9% EC @ 1 ml/L	500	23080	29.00	870000	319265	550735	3.18
T_9	Carbendazim 12% + Mancozeb 63% WP @ 2 g/L	1000	15360	26.68	800400	311545	488855	3.00
T_{10}	Copper Sulphate 47.15% + Mancozeb 30% WG @ 2 g/L	1000	16800	29.82	894600	312985	581615	3.33
T_{11}	Fluopyram 17.7% + Tebuconazole 17.7% SC @ 0.6 ml/L	300	26624	30.75	922500	322809	599691	3.33
T_{12}	Control (untreated)	-	-	16.31	489300	304185	185115	1.88

* Value of Grape considered at Rs. 35/kg; Average cost of cultivation excluding cost of input was considered Rs. 304185/ha;
Price of Propineb 70% WP = Rs. 1160/kg; Chlorothalonil 75% WP = Rs. 2129/kg; Mancozeb 75% WP = Rs. 700/kg; Zineb 75% WP = Rs. 1000/kg; Carbendazim 50% WP = Rs. 1550/kg; Thiophanate methyl 70% WP = Rs. 1550/kg; Hexaconazole 5% EC = Rs. 860/L; Tebuconazole 25.9% EC = Rs. 3770/L; Carbendazim 12% + Mancozeb 63% WP = Rs. 920/kg; Copper Sulphate 47.15% + Mancozeb 30% WG = Rs. 1100/Kg; Fluopyram 17.7% + Tebuconazole 17.7% SC = Rs. 7760/L; Labour Charges = Rs. 500/day and a total of 8 sprays are taken.

Field view of management

T_{12}: Control (untreated)

T_{11}: Fluopyram 17.7% + Tebuconazole 17.7% SC at 0.6 ml/L

T_{10}: Copper Sulphate 47.15% + Mancozeb 30% at WG 2 g/L

T_8: Tebuconazole 25.9% EC at 1 ml/L

Fig 1: Management of grape anthracnose during the back pruning 2024

T_{12}: Control (untreated)

T_{11}: Fluopyram 17.7% + Tebuconazole 17.7% SC at 0.6 ml/L

T_{10}: Copper Sulphate 47.15% + Mancozeb 30% at WG 2 g/L

T_8: Tebuconazole 25.9% EC at 1 ml/L

Fig 2: Management of grape anthracnose during the fore pruning 2024-25

4. Conclusion

Field evaluation demonstrated that chemical fungicides significantly reduced grape anthracnose severity and improved yield compared to the untreated control during both back and fore pruning seasons. Among the treatments, fluopyram 17.7% + tebuconazole 17.7% SC consistently recorded the lowest disease severity, highest reduction over control and maximum yield. Copper sulphate 47.15% + mancozeb 30% WG and tebuconazole 25.9% EC were also effective and statistically comparable in performance. Economic analysis confirmed that combination fungicides provided superior benefit-cost ratios, indicating higher profitability and cost efficiency.

5. Disclaimer (artificial intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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Competing Interests

Authors have declared that no competing interests exist.

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