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Interference of *Conyza sumatrensis* on grain yield of soybean cultivars

Interferencia de *Conyza sumatrensis* en la productividad de grano de cultivares de soya

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ABSTRACT

Sumatran fleabane (*Conyza sumatrensis*) weed can be found in several different agricultural environments and impacts different crops, such as soybean and maize. This weed may have a substantial impact on soybean yield. The aim was to evaluate the interference of *C. sumatrensis* on the grain yield of soybean cultivars. Soybean cultivars were used with late or early maturity, under 0, 1, 2, 3, 4, 6, 8, and 10 plants m^{-2} of *C. sumatrensis*. The four trials, composed of the two cultivars in each of the growing seasons, were analyzed separately. Because differences were found to be significant using the F-test in the comparison between trials ($P\leq 0.05$). The yield was subjected to analysis of variance and F-test. A nonlinear, rectangular hyperbolic regression model was fitted. For the early maturity cultivar, infestation levels of 17.1 and 17 of plants m^{-2} in the 2016–2018 and 2017–2018 growing seasons, respectively, were required to cause a 50% yield loss. For late-maturity cultivars, the values were 6.3 and 7.0 in the 2016–2017 and 2017–2018 growing seasons, respectively. The yield reduction observed for the late-maturity cultivar was 12.54 and 13.72% per plant of *C. sumatrensis,* in the 2016–2017 and 2017–2018 growing seasons, respectively. The early maturity cultivar showed a reduction of 9.35 and 10.77% per plant, in the 2016–2017 and 2017–2018 growing seasons, respectively. *Conyza sumatrensis* that cannot be tolerated in soybean, because a single plant per m^2 has great potential for reducing yield, from 9.35 to 13.72%.

Palabras clave:
Desempeño agronómico
Competición entre cultivos y malezas
Erigeron sumatrensis Retz
Maleza

RESUMEN

La maleza rama negra (*Conyza sumatrensis*) se puede encontrar en varios entornos agrícolas diferentes y afecta a diferentes cultivos, como la soja y el maíz. Esta maleza puede tener un impacto sustancial en la productividad de la soja. El objetivo fue evaluar la interferencia de *C. sumatrensis* en la productividad de grano de cultivares de soja. Se utilizaron cultivares de soja con madurez tardía o temprana, bajo 0, 1, 2, 3, 4, 6, 8 y 10 plantas m^{-2} de *C. sumatrensis*. Los cuatro ensayos, compuestos por los dos cultivares en cada una de las cosechas, se analizaron por separado. Debido a que se encontraron diferencias significativas utilizando la prueba F en la comparación entre ensayos ($P\leq 0,05$). La productividad fue sometida a análisis de varianza y prueba F. Se ajustó un modelo de regresión no lineal, hiperbólico rectangular. Para el cultivar de madurez temprana, se necesitaron niveles de infestación de 17,1 y 17 plantas m^{-2} en las cosechas 2016–2018 y 2017–2018, respectivamente, para causar una pérdida de productividad del 50%. Para el cultivar de madurez tardía, los valores fueron de 6,3 y 7,0 en las cosechas 2016–2017 y 2017–2018, respectivamente. La reducción de la productividad observada para el cultivar de madurez tardía fue del 12,54 y 13,72% por planta de *C. sumatrensis*, en las cosechas 2016–2017 y 2017–2018, respectivamente. El cultivar de madurez temprana mostró una reducción del 9,35 y 10,77% por planta, en las cosechas 2016–2017 y 2017–2018, respectivamente. *Conyza sumatrensis* no puede tolerarse en la soya, porque una sola planta por m^2 tiene un gran potencial para reducir la productividad, del 9,35 al 13,72%.

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Weed interference occurs through allelopathy, parasitism, and competition, which can affect crop development and yield (Horvath et al. 2023). This is especially true for the *Conyza* genus, with prolific weeds belonging to the Asteraceae family, as an example, the Sumatran fleabane (*Conyza sumatrensis* (Retz.) E. Walker sin.: *Erigeron sumatrensis* Retz.) (Bajwa et al. 2016). This weed has an annual life cycle, with high seed production, which can easily be dispersed longer distances from the parent plant (Liu et al. 2022). Thus, these plants can be found in several different agricultural environments, affecting crops, such as soybean and maize (Bajwa et al. 2016; Kalsing et al. 2024).

Trezzi et al. (2015) indicated that 2.7 *Conyza bonariensis* plants m^{-2} can reduce soybean yield by 50%. Agostinetto et al. (2017) reported that only one *C. bonariensis* plant m^{-2} can reduce soybean yield by up to 25.9%. Similarly, *Conyza canadensis* can reduce soybean yield by more than 90%, when chemical control measures are not adopted (Byker et al. 2013). In the southern region of Brazil in a subtropical climate, *C. sumatrensis* can reduce soybean grain yield by up to 50% (Blainski et al. 2015). In contrast, *C. sumatrensis* did not interfere with the agronomic performance of soybeans, in a study carried out in the Brazilian Cerrado biome during a hot and rainy summer. Under these conditions, the death of *C. sumatrensis* plants occurred, which can be explained due to shading by the crop (Correia 2023). In Brazil, there is a higher prevalence of *C. sumatrensis* than that of *C. bonariensis* in the southern region (Marochio et al. 2017; Ruiz et al. 2022). Including several reported cases of herbicide resistance for *C. sumatrensis* in this region of the country (Baccin et al. 2022; Heap 2024).

Twenty herbicide-resistant biotypes of *C. sumatrensis* have been reported worldwide (Heap 2024). In Brazil, there are cases of multiple resistance to chlorimuron and glyphosate (Santos et al. 2014), resistance to paraquat (Zobiole et al. 2019), and cases of single or multiple resistance to these and other herbicides (Pinho et al. 2019; Albrecht et al. 2020; Queiroz et al. 2020; Lorenzetti et al. 2024). Cases of herbicide resistance make it difficult to manage *Conyza* spp. and can increase production costs. The cost of managing glyphosate-resistant weeds in maize, cotton, and soybean fields in the United States alone has reached US$1 billion per year (Frisvold et al. 2017). Adegas et al. (2017) found that the control costs for herbicide-resistant *Conyza* spp. in Brazil were approximately 32% higher.

Weed interference studies can also assess the effects of weed-density and weed-crop proportions (Swanton et al. 2015). Weed management-related decisions mainly depend on an economic threshold, originating from the crop and cropping system. Furthermore, manipulation of soybean cultivars or growing seasons can increase crop competitiveness and change weed control decisions (Korres et al. 2020). *Conyza sumatrensis* may have a substantial impact on soybean yield. There are a few specific studies with this weed, which can be contrasting depending on the region of Brazil (Blainski et al. 2015; Correia 2023). Therefore, it is important to provide specific data for *C. sumatrensis*, given the prevalence of this species in Brazil (Ruiz et al. 2022; Kalsing et al. 2024). Thus, the aim was to evaluate the interference of *C. sumatrensis* on the grain yield of soybean cultivars.

MATERIALS AND METHODS

Weed-crop interference

Experiments were conducted in soybean fields at Palotina, Paraná, Brazil, during the 2016–2017 and 2017–2018 growing seasons using two soybean cultivars per season. The soils were very clayey (14% sand, 22% silt, and 64% clay), originated from basalt, and had a pH=5.9 and organic matter of 2.7%. The fields were managed under no-tillage, with a soybean-maize rotation system. The climate of the region is classified as Cfa according to the Köppen, with the weather conditions for the experimental period illustrated in Figure 1.

The cultivars M5947 and M6210 were sown on September 22 and 11, respectively, during the 2016–2017 growing season. In the 2017–2018 growing season, M5947 was sown on September 22 and M6210 on October 4 (following seed companies' recommendations). M6210 (late maturity cultivar - maturity group 6.2) has a longer cycle than M5947 (early maturity cultivar - maturity group 5.9). Both soybean cultivars have indeterminate growth habits. In the 2016-2017 growing season, fertilization was carried out at sowing with 206 kg ha^{-1} of fertilizer 02-20-18 (NPK), for the 2017-2018 growing season, 248 kg ha^{-1} of fertilizer 02-18-18 (NPK) was used. Phytosanitary management was carried out to keep the crop free of biotic factors

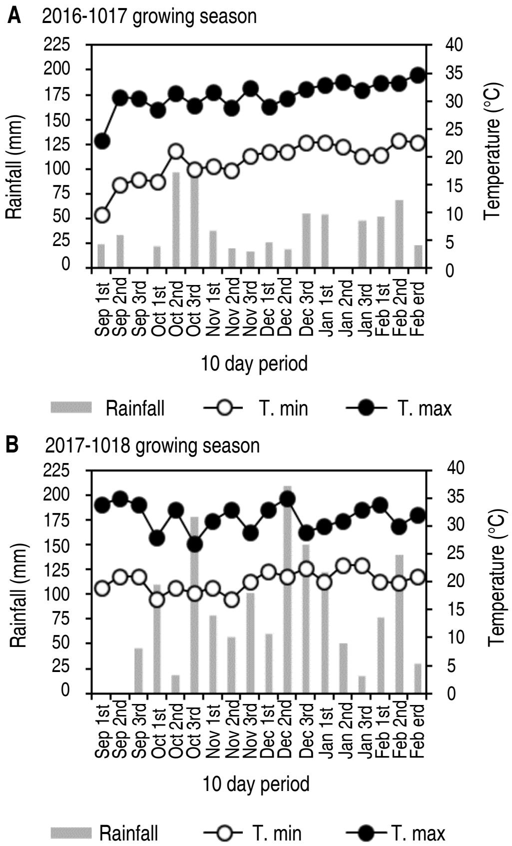

Figure 1. Rainfall, maximum (T. max), and minimum temperature (T. min) during the period of the experiments, 2016-2017 (A) and 2017-2018 (B) growing seasons.

that could interfere with the growth and development of soybean plants, following technical recommendations appropriate for the region.

The experimental design was a randomized complete block design, with three and four repetitions in 2016–2017 and 2017–2018, respectively. The treatments consisted of different densities of *C. sumatrensis*: 0, 1, 2, 3, 4, 6, 8, and 10 plants m^{-2}. The plots consisted of six 5 m long rows of soybean plants spaced at 0.45 m, adding up to 13.5 m^2 for each plot. To obtain the desired populations at the four trials, the plots were completely weeded manually up to 14 days before soybean sowing. *C. sumatrensis* plants that coexisted with soybeans emerged from this date. During soybean sowing, *C. sumatrensis* plants were up to 10 cm tall and had 1 to 3 leaves. From soybean sowing until approximately 40 days after emergence (closure between rows), weeding was carried out to maintain *C. sumatrensis* densities and control weeds of other species. Weeding was carried out once a week. For all four trials, there was a large infestation of *C. sumatrensis* before weeding began (approximately 15 plants m^{-2}). Plants with the best distribution throughout the plot were chosen, and those present in the space between the soybean rows were prioritized. As weeding progressed, new emergence flushes of *C. sumatrensis* were easily identified. Young seedlings were eliminated, while those previously selected were larger. No herbicides were used to control weeds; all control was carried out by hand weeding, to avoid any herbicide injury on soybeans or *C. sumatrensis*.

Furthermore, soybeans were harvested manually at the R_8 stage (full maturity). The plants of the two central rows were harvested at 4 m in length, adding up to 3.6 m^2. The grains produced in each plot were weighed, and the moisture was corrected to 13%. Furthermore, the yield in kg ha^{-1} was calculated using this data.

Analysis of yield loss and critical level of losses

The four trials, composed of the two cultivars in each of the growing seasons, were analyzed separately. Because differences were found to be significant using the F-test in the comparison between trials ($P \leq 0.05$). Yield data were subjected to the analysis of variance by F-test ($P \leq 0.05$) using the Sisvar 5.6 software (Ferreira 2011). A nonlinear, rectangular hyperbola regression model was fitted to the data using SigmaPlot 12 software (Kalsing and Vidal 2013; Machado et al. 2015), following Equation 1:

$$y = \frac{a * x}{b + x} \tag{1}$$

Wherein "y" is equivalent to the normalized data for the yield loss in comparison to the weed-free plots, expressed as a percentage (%); "a" is the maximum asymptote or yield loss when the weed density is close to the carrying capacity of the environment; "b" is the level of infestation that is equivalent to approximately 50% yield reduction, and "x" is the level of infestation. The critical level of damage (i) was then obtained by the ratio between parameters "a" and "b" of the equation, representing the impact of each plant on the crop yield.

RESULTS AND DISCUSSION

Conyza sumatrensis substantially reduced soybean yield even under low densities in both cultivars and seasons. For the early maturity soybean cultivar, infestation levels of 17.1 and 17 (parameter b) of *C. sumatrensis* m^{-2} in the 2016–2017 and 2017–2018 growing seasons, respectively, were required to cause a 50% yield loss of soybean crop. For the late-maturity cultivar, the values were 6.3 and 7.0 in the 2016–2017 and 2017–2018 growing seasons, respectively. In the 2016–2017 growing season, the parameter "i" (proportional yield loss when the weed density approaches zero) was 12.5% for the late-maturing cultivar and 9.35% for the early-maturity cultivar. In the 2017–2018 growing season, the parameter "i" was 13.7% for the late-maturity cultivar, whereas it was 10.77% for the early-maturity cultivar, which was 22% lower compared to the late-maturity cultivar. That is, a single plant of *C. sumatrensis* m^{-2} can reduce soybean yield by up to 13.7% (Table 1).

Table 1. Equation parameters obtained by nonlinear rectangular hyperbole regression, for early and late maturity soybean cultivars and growing season.

Growing season	Cultivar	Equation parameters			
		a	b	i (%)	R^2
2016-2017	Early maturity	159.1±63.2	17.1±9.9	9.35	0.93
	Late maturity	79.1±18.0	6.3±2.9	12.54	0.89
2017-2018	Early maturity	183.2±48.2	17.0±6.3	10.77	0.95
	Late maturity	96.1±6.6	7.0±0.9	13.72	0.98

a: maximum asymptote. b: the value of the level of infestation that equals 50% of yield reduction. i: soybean yield loss per weed unit when its density approaches zero.

Trezzi et al. (2015) indicated that 2.7 of *C. bonariensis* m^{-2} plants could reduce soybean yield by approximately 50%, which is higher than that observed in the present study. Moreover, Agostinetto et al. (2017) found that a single plant m^{-2} of *C. bonariensis* could reduce soybean yield by approximately 25.9%. In contrast, *C. sumatrensis* at densities of 13 to 23 plants m^{-2} did not interfere with the agronomic performance of soybeans, in a study carried out in the Brazilian Cerrado biome during a hot and rainy summer. Under these conditions, the death of *C. sumatrensis* plants occurred, which can be explained due to shading by the crop (Correia 2023). In the southern region of Brazil in a subtropical climate, such as this study, 20 to 35 plants m^{-2} of *C. sumatrensis* can reduce soybean grain yield by up to 50% (Blainski et al. 2015). Weed interference can be highly dependent on the cultivar and weed genotypes and the present environment (Roncatto et al. 2021; Caldas et al. 2023). Therefore, comparative tests can be conducted to determine the tolerance of cultivars at different environments in comparison with the weeds.

The current study identified that for both cultivars, growing seasons, and densities used, *C. sumatrensis* has a substantial impact on soybean yield. There are a few specific studies on *C. sumatrensis*, which can be contrasting depending on the soil and climate conditions (Correia 2023). Therefore, it is important to provide specific data for *C. sumatrensis* in a subtropical climate, given the prevalence of this species in the southern region of Brazil (Marochio et al. 2017; Ruiz et al. 2022), which reiterates the relevance of this study. Other weeds highlighted for their negative impact on soybean yield include *Amaranthus palmeri* (Korres et al. 2019), *Digitaria insularis* (Gazziero et al. 2019), and *Amaranthus tuberculatus* (Butts et al. 2018), which are among the most important weeds in soybean crop.

In the 2016–2017 growing season, the early maturity cultivar had a grain yield in the absence of *C. sumatrensis* was 3,992 kg ha^{-1}. For the highest level of infestation (10 plants m^{-2}) the average yield reduction was 58%, with a grain yield of 1,677 kg ha^{-1}. Moreover, the late-maturing cultivar had a grain yield of 3,861 kg ha^{-1} in the absence of *C. sumatrensis*. The maximum loss (48%) was observed at the highest level of infestation (10 plants m^{-2}), with a grain yield of 2,008 kg ha^{-1} (Figure 2).

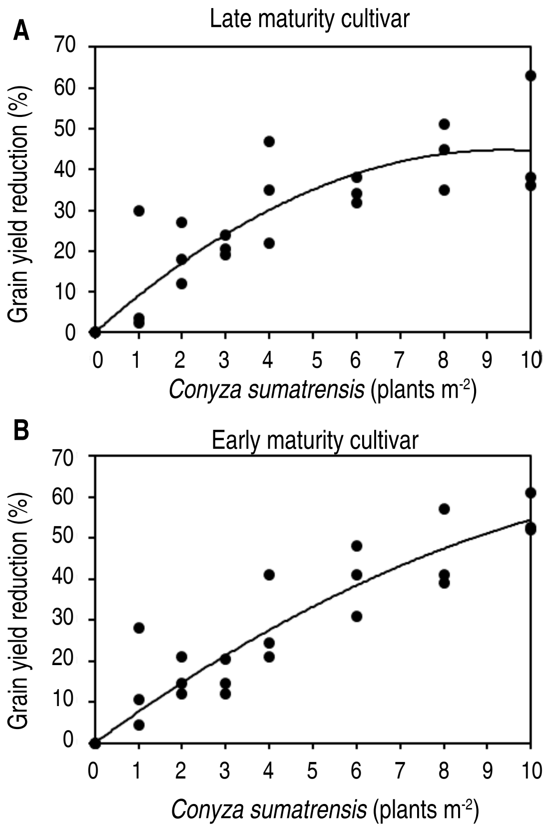

Figure 2. Nonlinear regression of rectangular hyperbole for soybean yield reduction under densities of *C. sumatrensis*. Late (A) and early (B) maturity soybean cultivars, 2016-2017 growing season.

In 2017–2018, the grain yield for the late-maturing cultivar was 4,311 kg ha^{-1} without weed infestation, with maximum loss (57%) for 10 plants m^{-2} with a grain yield of 1,854 kg ha^{-1}. The early maturity cultivar produced 4,019 kg ha^{-1} in the absence of infestation. Under the influence of 10 plants m^{-2} the yield was reduced by 73%, with a grain yield of 1,085 kg ha^{-1} (Figure 3).

At maximum infestation (10 plants m^{-2}), there was a minimum reduction of 48.7% in soybean yield. These results show the substantial influence of *C. sumatrensis* on soybeans, making it necessary to maintain weed density at the lowest level, or absent, because even a single plant of *C. sumatrensis* m^{-2} has a considerable impact on soybean yield, until 13.72%. Trezzi et al. (2015) concluded that a single plant of *C. bonariensis* m^{-2} can reduce soybean grain yield by up to 36%. Competition between *C. bonariensis* and soybeans between 21 and 42 days after crop emergence can represent a reduction of 21 kg ha^{-1} in yield per day of coexistence (Silva et al. 2014). This reinforces the need to keep soybean crops free from the presence of *Conyza* spp.

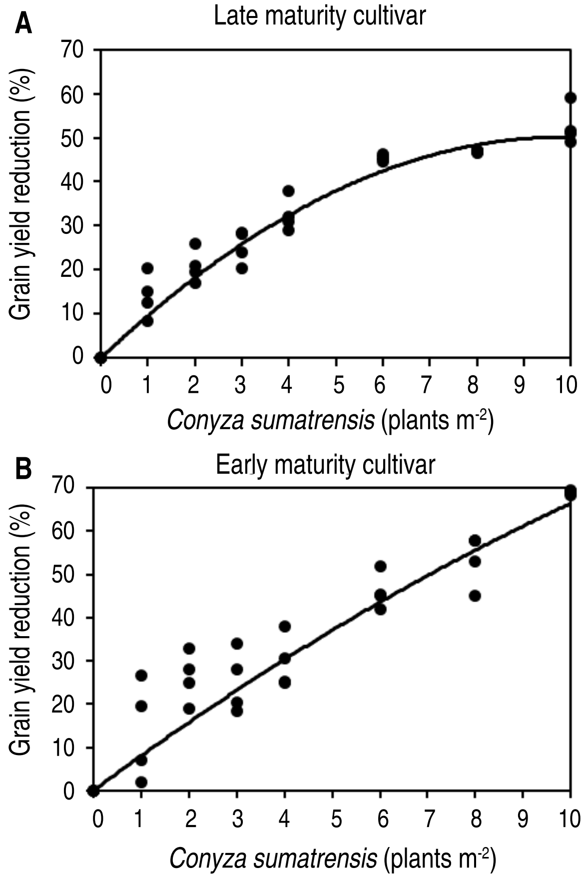

Figure 3. Nonlinear regression of rectangular hyperbole for soybean yield reduction under densities of *C. sumatrensis*. Late (A) and early (B) maturity soybean cultivars, 2017-2018 growing season.

Some characteristics help in explaining the high aggressiveness of *Conyza* spp. plants, including vigorous growth, plasticity in their life cycle, and their ability to adapt to different environments (Bajwa et al. 2016; Baccin et al. 2022). As well as when in competition, it can affect the growth and development of soybean shoots and roots (Rockenbach and Rizzardi 2020). Furthermore, some studies have also indicated the allelopathic effects of *Conyza* spp. on other plant species (Ferreira et al. 2020; Peralta et al. 2022). *Conyza* species were dominant in some environments, with the presence of few weeds of other species (Concenço and Concenço 2016). The ecophysiological characteristics of *Conyza* associated crop management, no-till system, continuous use of herbicides for control, and other aspects have favored the selection of resistant biotypes and dominance of this weed (Bajwa et al. 2016; Baccin et al. 2022). Therefore, this reinforces the competitive ability of this plant, even about other weeds, and helps in explaining the impact of a single m^{-2} plant on soybean yield in the present study. The aggressiveness of *Conyza* spp. restates the importance of effective control, which keeps the population levels of this plant close to zero. In this study, this is reinforced by the data obtained for *C. sumatrensis*. Thus, the adoption of herbicides in pre- or post-emergence in combinations (Cantu et al. 2021; Albrecht et al. 2022; Garcia et al.

2023; Monteiro et al. 2024), cover crops (Wallace et al. 2019; Bunchek et al. 2020; Fisher and Sprague 2022, 2023), and herbicide combinations with cover crops (Schramski et al. 2021) are fundamental for the control of this and other weeds. For example, vetch and barley crop residues were effective in suppressing *C. canadensis* (Campiglia et al. 2015), also maize, *Urochloa*, ryegrass, turnip, wheat, and black oat crop residues were effective in suppressing *C. bonariensis* (Lamego et al. 2013). Which, in the sum of research, highlights the need for integrated weed management.

The adoption of these and other practices for the management of *Conyza* spp. is not only important for controlling and suppressing low population densities but also for controlling the advance of herbicide-resistant biotypes. Therefore, the presence of even a single plant m^{-2} of *C. sumatrensis* should not be tolerated. This condition must be sought in integrated weed management, with the aim of achieving economic sustainability in soybean crops (Bajwa et al. 2016; Riemens et al. 2022). The integration of control methods is important, with preference given to those that reduce the emergence of weeds, such as crop rotation that provides soil cover with crop residues. Hand weeding is very expensive, and it becomes unfeasible even for small areas to control aggressive weeds, estimates indicate that a rural worker needs 15 days to weed one hectare, with successive interventions in order to keep the crop free from weed interference (Van der Weide et al. 2008). The cost of manual weeding can approach US$ 200 ha^{-1}, a high cost per hectare, it was not considered a viable option in the economic analysis (Dominschek et al. 2021).

Thus, the adoption of herbicides in pre- or post-emergence combinations, cover crops, and herbicide combinations with cover crops are fundamental for the control of this and other weeds. However, there are a few studies on *C. sumatrensis*, whereas most of the interference studies have been conducted on other species of *Conyza*. Therefore, extensive research on different production systems and agroecosystems needs to be carried out. Comparative tests can be conducted to determine the tolerance of cultivars in comparison with the weeds.

CONCLUSION

The grain yield reduction observed for the late-maturity cultivar was 12.54 and 13.72% per plant of *C. sumatrensis*, in the 2016–2017 and 2017–2018 growing seasons, respectively. The early maturity cultivar showed a reduction of 9.35 and 10.77% per plant of *C. sumatrensis*, in the 2016–2017 and 2017–2018 growing seasons, respectively. *Conyza sumatrensis* cannot be tolerated in soybean crops, because a single plant per m^2 has great potential for reducing grain yield.

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