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RESEARCH ARTICLE

Soil Water Content Below 33.7% Progressively Reduces the Latex Yield of Rubber PB 60, A Study in Sembawa, South Sumatra, Indonesia

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Abstract

Rubber is one of the economically important tropical trees that produces natural rubber, an essential industrial raw material in Indonesia. In general, rubber can grow well in areas with 1,500 - 3,000 mm rainfall per year that evenly distributed round the year. During the dry season, water availability is reduced so that water becomes a limiting factor for the growth and production of the rubber tree. This paper aimed to determine minimum soil water content that must be maintained to prevent the reduction of PB 260 rubber production based on field water balance. This research was carried out at the Indonesian Rubber Research Institute Experimental Field, South Sumatra, Indonesia, between 2014 to 2019. This experiment used PB 260 clone which was planted in 2001 using a 6 x 3 m plant spacing. Soil analysis showed that the Sembawa had a clay loam soil texture. The measured parameters were latex production (kg per ha per year), rainfall, and evapotranspiration (mm). The results from our six years of study showed that rubber production always decreased when soil water content started to decline below field capacity (33.7 %, or equal to 337 mm with 1m depth of root zone).

Keywords: PB 260 clone, evapotranspiration, soil water content, water availability

Introduction

Rubber is one of the economically important tropical trees that produces natural rubber, an essential industrial raw material in Indonesia. According to the Directorate General of Plantation (2018) Indonesia's rubber exports in 2017 amounted 2.99 million tons with a value of US $ 5.10 billion. Climate factors can significantly affect the development and production of rubber. Minimum rainfall for rubber is 1,500 mm per year that evenly distributed round the year (Dijkman, 1951 and William et al., 1980). The amount of evapotranspiration or water required by rubber tree is equal to 3-5 mm per day for conditions in Indonesia (Haridas, 1985). Rainfall of 100-150 mm can fulfill the water demand of rubber for one month (Rao and Vijayakumar, 1992). During the dry season, water availability is reduced so that water becomes a limiting factor for the growth and production of rubber. This is especially notable in rubber plantations where high density plant spacing leads to competition over the remaining water in the soil. Kramer (1983) stated that the prolonged drought direct effect is the reduction of growth rate and production. Fluctuation of rubber production in Indonesia often occur due to wintering season, or an annual event where the leaves of the rubber tree die and fall off, and new leaves are formed. Siregar (2007) said that rubber leaf fall dynamics of PB 260 and RRIM 712 rubber clones follow rainfall dynamics throughout the year. This indicates that soil water content affects the condition of rubber leaves. During dry season, rainfall decreases so water becomes a limiting factor for the growth of rubber plants. With limitations of water during the dry season, rubber plants adapt to the new condtion through reducing transpiration by shedding their leaves. Water shortages in plants occur when water loss through transpiration is greater than water absorption by roots. Low soil water content or dry atmosphere condition can cause a mild water deficit. This can inhibit some plant physiological processes so that the rate of plant metabolic process will be lower than normal condition (Husni and Daslin, 1995). Thomas and Boerhendhy (1988) stated that PR 261 and GT1 clones have different responses in terms of water deficits. PR 261 clone shed their leaves during water deficit period, while GT1 clone dropped their leaves after the water deficit period. This paper aimed to determine the minimum soil water content that must be maintained to prevent the decline in rubber production of PB 260 clone based on land water balance calculations.

Material and Methods

This research was carried out at the Indonesian Rubber Research Institute Experimental Field, South Sumatra, Indonesia from 2014 to 2019. The experiment used rubber clone PB 260 which was planted in 2001 at 6 x 3 m of plant spacing. Soil analysis showed that the area had a clay loam soil texture. The parameters measured were latex production (kg/ha/year), rainfall, and evapotranspiration (mm) for six years (2014-2019). Agroclimatic data of 2014 - 2019 was obtained from Climatological Station of Indonesian Rubber Research Institute in Sembawa. Soil analysis to determine soil water content at the permanent wilting point (pF 4.2) and field capacity (pF 2.54) were carried out by physical analysis methods in the laboratory (Bayer et al., 1972).

Potential evapotranspiration (ETP) was calculated by method from Savva and Frenken (2002):

ETP = Kp x Epan
where:
ETP = Potential evapotranspiration (mm per day)
Kp = Pan coefficient (0.85)
Epan = Pan evaporation (mm per day)

Furthermore, soil water content was calculated using a field water balance calculation (Nasir and Effendy, 2000):
In = Out
P = ETP + S
ETA = P + |dSWC|
D = ETP - ETA
S = P - ETP - dSWC

where:
P = Precipitation (rainfall)
ETP = Potential evapotranspiration
ETA = Actual evapotranspiration
SWC = Soil water content
dSWC = Change of soil water content
D = Water/evapotranspiration deficit
S = Water surplus
FC = Soil water content at field capacity
a = Absolute value of APWL (accumulation of potential water loss)
APWL = Accumulation of negative value of P-ETP
k = $P_0 + (P_1/FC)$
P0 = 1,000412351
P1 = -1,073807306

In this paper, the soil water content, evapotranspiration deficit, and PB 260 rubber production have been plotted in a chart to determine the level of soil water content that triggered the reduction of PB 260 rubber production by using Microsoft Excell (Microsoft, 2012). Furthermore, the regression and correlation between the soil water content, water (evapotranspiration) deficit, and PB 260 rubber production had been conducted using Statistical Package for the Social Sciences (SPSS) software (IBM Corporation, 2012).

Results and Discussion

Rainfall affected soil water content fluctuation. The soil water content fluctuation also affects plant metabolism and production. The condition of rainfall and rubber production in the study site for six years can be seen in Figure 1. Rainy season started in November to May, and dry season began from June to October. The lowest rainfall for six years occurred in October 2015, which was only 0.6 mm with a rubber production of 938 kg/ha/year. In 2018 and 2019, the lowest rainfall was occurred in July and September as high as 2.6 and 7.5 mm with rubber production of 791 and 520 kg/ha/year respectively. Rainfall influenced crop production significantly. The total rainfall is very important in determining crop yields (Anwar et al., 2015). Furthermore, Sahuri and Cahyo (2018) found that rainfall had a positive correlation with BPM 24 rubber clone production on the same month until the following three months. Moreover, Mak et al. (2008) reported a higher latex yield during rainy season even though irrigation was performed on the experimental plot.

Apart from the rainfall factor, there are several other factors related to water that affect rubber production, including soil water content and evapotranspiration deficit. Soil water content and evapotranspiration deficit of a land can be determined through the calculation of water balance (Table 1).

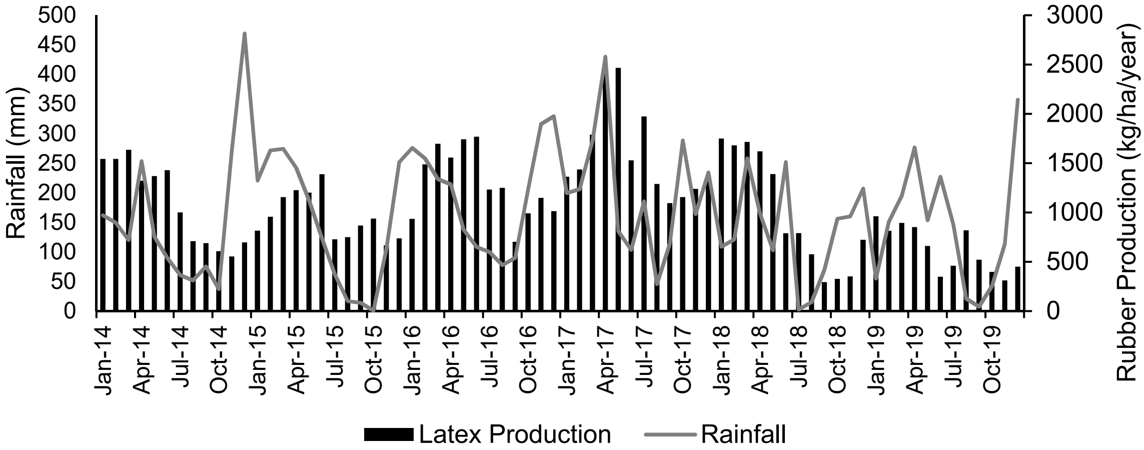

Figure 1. Rainfall and rubber production in Sembawa, South Sumatra, Indonesia from 2014-2019

Table 1. Water availability in Sembawa, South Sumatra, Indonesia, from 2014 to 2019

Month	P (mm)	ETP (mm)	P - ETP (mm)	APWL (mm)	|APWL| (mm)	SWC (mm)	dSWC (mm)	|dSWC| (mm)	ETA (mm)	D (mm)	S (mm)
Jan-14	162.0	94.3	67.7	0.0	0.0	337.0	0.0	0.0	94.3	0.0	67.7
Feb-14	149.3	84.9	64.4	0.0	0.0	337.0	0.0	0.0	84.9	0.0	64.4
Mar-14	120.0	86.4	33.6	0.0	0.0	337.0	0.0	0.0	86.4	0.0	33.6
Apr-14	253.2	88.0	165.2	0.0	0.0	337.0	0.0	0.0	88.0	0.0	165.2
May-14	125.6	87.0	38.6	0.0	0.0	337.0	0.0	0.0	87.0	0.0	38.6
Jun-14	89.6	90.4	-0.7	-0.7	0.7	336.3	-0.7	0.7	90.3	0.0	0.0
Jul-14	60.8	91.2	-30.4	-31.1	31.1	309.1	-27.3	27.3	88.0	3.2	-3.2
Aug-14	51.8	88.6	-36.8	-67.9	67.9	279.1	-30.0	30.0	81.8	6.8	-6.8
Sep-14	75.4	99.9	-24.5	-92.4	92.4	260.7	-18.3	18.3	93.7	6.1	-6.1
Oct-14	37.4	85.9	-48.5	-140.9	140.9	227.8	-32.9	32.9	70.3	15.6	-15.6
Nov-14	271.3	92.2	179.1	0.0	0.0	337.0	109.2	109.2	92.2	0.0	69.9
Dec-14	469.0	44.2	424.8	0.0	0.0	337.0	0.0	0.0	44.2	0.0	424.8
Jan-15	220.8	76.7	144.1	0.0	0.0	337.0	0.0	0.0	76.7	0.0	144.1
Feb-15	271.5	72.6	198.8	0.0	0.0	337.0	0.0	0.0	72.6	0.0	198.8
Mar-15	274.3	81.0	193.3	0.0	0.0	337.0	0.0	0.0	81.0	0.0	193.3
Apr-15	242.0	79.0	162.9	0.0	0.0	337.0	0.0	0.0	79.0	0.0	162.9
May-15	187.3	78.0	109.3	0.0	0.0	337.0	0.0	0.0	78.0	0.0	109.3
Jun-15	123.1	75.5	47.6	0.0	0.0	337.0	0.0	0.0	75.5	0.0	47.6
Jul-15	62.0	79.7	-17.7	-17.7	17.7	320.8	-16.2	16.2	78.2	1.5	-1.5
Aug-15	16.9	134.3	-117.3	-135.0	135.0	231.6	-89.2	89.2	106.2	28.1	-28.1
Sep-15	14.0	122.0	-108.0	-243.0	243.0	171.6	-60.0	60.0	74.0	48.0	-48.0
Oct-15	0.6	128.5	-127.9	-370.9	370.9	120.3	-51.3	51.3	51.9	76.6	-76.6
Nov-15	105.2	110.9	-5.7	-376.7	376.7	118.4	-1.9	1.9	107.1	3.8	-3.8
Dec-15	251.7	115.5	136.2	0.0	0.0	254.6	136.2	136.2	115.5	0.0	0.0
Jan-16	275.9	118.7	157.2	0.0	0.0	337.0	82.4	82.4	118.7	0.0	74.7
Feb-16	258.0	103.2	154.8	0.0	0.0	337.0	0.0	0.0	103.2	0.0	154.8
Mar-16	223.0	116.5	106.5	0.0	0.0	337.0	0.0	0.0	116.5	0.0	106.5
Apr-16	214.0	108.5	105.5	0.0	0.0	337.0	0.0	0.0	108.5	0.0	105.5
May-16	137.6	117.4	20.2	0.0	0.0	337.0	0.0	0.0	117.4	0.0	20.2
Jun-16	108.3	107.6	0.8	0.0	0.0	337.0	0.0	0.0	107.6	0.0	0.8

Month	P (mm)	ETP (mm)	P - ETP (mm)	APWL (mm)	|APWL| (mm)	SWC (mm)	dSWC (mm)	|dSWC| (mm)	ETA (mm)	D (mm)	S (mm)
Jul-16	99.9	112.9	-13.0	-13.0	13.0	325.0	-12.0	12.0	111.9	1.1	-1.1
Aug-16	77.6	122.0	-44.4	-57.4	57.4	287.3	-37.7	37.7	115.3	6.7	-6.7
Sep-16	90.1	110.1	-20.0	-77.4	77.4	271.8	-15.5	15.5	105.6	4.5	-4.5
Oct-16	206.2	129.0	77.2	0.0	0.0	337.0	65.2	65.2	129.0	0.0	12.0
Nov-16	315.9	88.9	227.0	0.0	0.0	337.0	0.0	0.0	88.9	0.0	227.0
Dec-16	329.3	94.9	234.5	0.0	0.0	337.0	0.0	0.0	94.9	0.0	234.5
Jan-17	199.4	100.3	99.1	0.0	0.0	337.0	0.0	0.0	100.3	0.0	99.1
Feb-17	205.9	91.7	114.2	0.0	0.0	337.0	0.0	0.0	91.7	0.0	114.2
Mar-17	288.2	107.3	180.9	0.0	0.0	337.0	0.0	0.0	107.3	0.0	180.9
Apr-17	430.0	108.0	322.0	0.0	0.0	337.0	0.0	0.0	108.0	0.0	322.0
May-17	135.3	115.9	19.4	0.0	0.0	337.0	0.0	0.0	115.9	0.0	19.4
Jun-17	103.3	100.5	2.8	0.0	0.0	337.0	0.0	0.0	100.5	0.0	2.8
Jul-17	185.5	87.3	98.2	0.0	0.0	337.0	0.0	0.0	87.3	0.0	98.2
Aug-17	45.6	120.3	-74.7	-74.7	74.7	273.9	-63.1	63.1	108.7	11.5	-11.5
Sep-17	113.7	191.5	-77.8	-152.5	152.5	220.6	-53.2	53.2	166.9	24.6	-24.6
Oct-17	288.3	110.2	178.1	0.0	0.0	337.0	116.4	116.4	110.2	0.0	61.7
Nov-17	164.1	99.1	65.0	0.0	0.0	337.0	0.0	0.0	99.1	0.0	65.0
Dec-17	234.3	80.8	153.5	0.0	0.0	337.0	0.0	0.0	80.8	0.0	153.5
Jan-18	108.8	88.5	20.3	0.0	0.0	337.0	0.0	0.0	88.5	0.0	20.3
Feb-18	121.2	65.6	55.6	0.0	0.0	337.0	0.0	0.0	65.6	0.0	55.6
Mar-18	258.0	85.3	172.7	0.0	0.0	337.0	0.0	0.0	85.3	0.0	172.7
Apr-18	165.1	102.9	62.2	0.0	0.0	337.0	0.0	0.0	102.9	0.0	62.2
May-18	102.9	99.4	3.5	0.0	0.0	337.0	0.0	0.0	99.4	0.0	3.5
Jun-18	251.7	103.9	147.8	0.0	0.0	337.0	0.0	0.0	103.9	0.0	147.8
Jul-18	2.6	129.8	-127.2	-127.2	127.2	236.7	-100.3	100.3	102.9	26.9	-26.9
Aug-18	15.4	85.7	-70.3	-197.5	197.5	194.7	-42.0	42.0	57.4	28.3	-28.3
Sep-18	69.8	124.4	-54.6	-252.1	252.1	167.3	-27.4	27.4	97.2	27.2	-27.2
Oct-18	156.1	144.3	11.8	0.0	0.0	179.1	11.8	11.8	144.3	0.0	0.0
Nov-18	160.0	101.1	58.9	0.0	0.0	238.1	58.9	58.9	101.1	0.0	0.0
Dec-18	207.0	90.6	116.4	0.0	0.0	337.0	98.9	98.9	90.6	0.0	17.5
Jan-19	55.0	111.9	-56.9	-56.9	56.9	287.7	-49.3	49.3	104.3	7.6	-7.6
Feb-19	151.0	99.8	51.2	0.0	0.0	337.0	49.3	49.3	99.8	0.0	2.0
Mar-19	195.0	97.5	97.5	0.0	0.0	337.0	0.0	0.0	97.5	0.0	97.5
Apr-19	276.6	99.5	177.1	0.0	0.0	337.0	0.0	0.0	99.5	0.0	177.1
May-19	153.4	119.5	33.9	0.0	0.0	337.0	0.0	0.0	119.5	0.0	33.9
Jun-19	226.8	91.8	135.0	0.0	0.0	337.0	0.0	0.0	91.8	0.0	135.0
Jul-19	146.0	123.3	22.7	0.0	0.0	337.0	0.0	0.0	123.3	0.0	22.7
Aug-19	21.1	147.9	-126.8	-126.8	126.8	236.9	-100.1	100.1	121.2	26.8	-26.8
Sep-19	7.5	146.2	-138.7	-265.6	265.6	161.2	-75.8	75.8	83.3	63.0	-63.0
Oct-19	42.4	141.2	-98.8	-364.3	364.3	122.5	-38.7	38.7	81.1	60.1	-60.1
Nov-19	113.6	133.5	-19.9	-384.2	384.2	115.9	-6.6	6.6	120.2	13.3	-13.3
Dec-19	357.4	102.7	254.7	0.0	0.0	337.0	221.1	221.1	102.7	0.0	33.7

Note: P = Rainfall; ETP = potential evapotranspiration; APWL = Accumulation of potential water loss; SWC = soil water content; ETA = actual evapotranspiration; D = water deficit and S = water surplus.

Table 1 showed the result of the calculation of field water balance in Sembawa area for six years (2014-2019). Using rainfall data, potential evapotranspiration, and soil pF curves, fluctuations in soil water content and evapotranspiration deficits in this area can be calculated. Stevanus et al., (2017) stated that soil texture in Sembawa area is classified as clay loam. For this type of soil texture, field capacity and permanent wilting point can be achieved at 33.7% and 18.5% of soil water content, respectively (Stevanus et al., 2017). The depth of rubber root zone based on this calculation is assumed to be as deep as 1 m.

Based on data in Table 1, calculation of field water balance, the maximum amount of water that can be stored by soil with a depth of 1 m is 337 mm. Therefore, if soil water content reaches more than 337 mm, the excess will be moved to other areas by runoff, percolation, or seepage. This soil water content fluctuates in accordance with fluctuations in rainfall and potential evapotranspiration. If the potential evapotranspiration is greater than rainfall, there will be a loss of water from the soil. The increase in accumulation of potential water loss (APWL) value resulted in the greater reduction of soil water content. Decrease in soil water content at a certain point causes plants to experience drought stress. At the permanent wilting point, plants cannot uptake water from the soil. Groundwater is only available for plants in the range of field capacity to permanent wilting points (Allen, 1998; Doorenboss and Pruit, 1977; Savva and Franken, 2002, Waller and Yitayew, 2016). From the value of soil water content which is obtained in the previous calculation, it can be calculated value of actual evapotranspiration (ETA) and transpiration deficit. The ETA value is the same as the potential evapotranspiration (ETP) if APWL value = 0, whereas if APWL value ≥ 0, the ETA value can be calculated by adding rainfall in the month-i and the absolute value of the change in soil water content in the month-i. If the calculation results value of ETA > ETP, the value of ETA is considered the same as ETP. From the results of these calculations, the evapotranspiration deficit value can be determined by calculating the difference between the ETP and ETA (Djufry, 2015).

Table 1 also demonstrated that in 2014 with annual rainfall amounted to 1865 mm per year, the surplus in water availability occurred from January to June. From July to October 2014, the availability of water began to decrease as seen by the value of transpiration deficit that could not be covered through rainfall. In 2015 – 2019, the lowest water availability occurred in July - October. This is in line with the decrease in rainfall intensity for the same months. Plants with enough water will be able to maintain their stomata opening to ensure a smooth exchange of gases in the leaves including CO_2 which was useful in photosynthesis activity so that high photosynthesis activity can guarantee the rate of plant growth (Bayer, 1976).

From the calculation of soil water content and evapotranspiration deficit, the effect on fluctuations in rubber production can be determined. The graph of relationship between fluctuations in soil water content, evapotranspiration deficit, and production of PB 260 rubber clone planted in 2001 is presented in Figure 2.

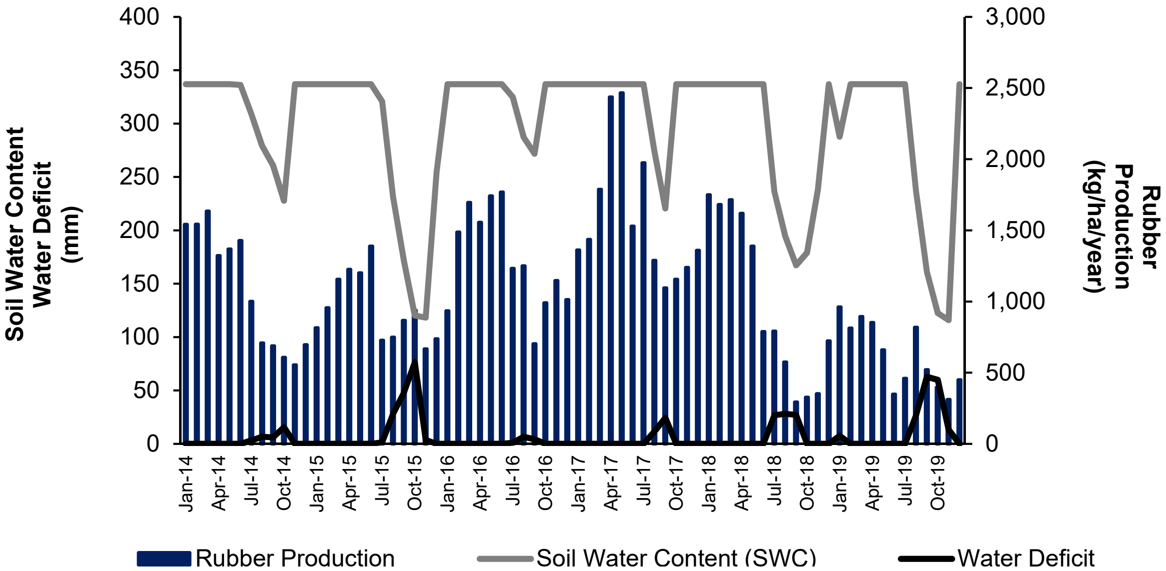

Figure 2. Soil water content, water deficit and rubber production in Sembawa, South Sumatra, Indonesia, from 2014 to 2019

Figure 2 showed the relationship between soil water content, water deficit and rubber production for six years. The highest water deficit occurred in October 2015 and amounted to 76.59 mm with a condition of soil water content of 120.26 mm. The highest rubber production in April 2017 occurred when soil conditions did not experience a water deficit. Water deficit results in reduced photosynthesis or all physiological processes become abnormal. It also resulted in stunted plants, low production and decreased quality (Craft et al, 1949; Kramer, 1969). Soil water content and rubber production (2014 – 2019) were significantly correlated with correlation value of 0.53. In areas with low rainfall, water will be the main problem. Thomas et al (2008) reported a retardation in immature rubber stem growth rate as high as 0.65 cm/month during drought period in South Sumatra region. The use of irrigation method was inefficiently applied in a large rubber plantations because it required a high cost. An effort that can be conducted to maintain water availability in the soil is by applying soil pit. According to research conducted by Bohluli et al. (2012) in oil palm plantations, soil pit with various sizes increased the availability of soil water content from 1.46 - 19.22% compared to control. Furthermore, Figure 2 showed that rubber production always decreased when soil water content started to be less than field capacity (337 mm). The decline in rubber production always occurred when soil water content declined to be smaller than 337 mm, although at that time crop production curve was moving up, down, or flat at both high and low levels of rubber production. Conversely, the rubber production curve always moves up when the value of evapotranspiration deficit falls to 0. This shows that rubber PB 260 production in Sembawa is optimal when soil water content reaches the field capacity of 33.7%.

Conclusion

Soil water content and rubber production from 2014-2019 were significantly correlated with correlation value of 0.53. Rainfall < 100 mm per month reduced the rubber production. Decline in rubber production with root zone depth of 1 m always occurred when soil water content curve declined to be <337 mm, or 33.7%. In contrast, rubber production curve moved up when the value of evapotranspiration deficit fell to 0 mm.

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