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Influence of Soil Conditions on Growth of Hevea: *Glasshouse Evaluations*

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The influence of soil conditions using the 'least-disturbed soil' sample technique on growth of rubber was studied. Tjir 1 seedlings grown on friable, clayey soils with good physical properties produced the highest dry matter. The Oxisols (Kuantan, Munchong, Segamat, Malacca and Holyrood series) produced more dry matter than the Ultisols (Serdang, Rengam, Chat, Durian and Harimau series). The Entisols (Linau and Briah series) when drained were average in dry matter productivity. The Entisol associated with a high water-table (Linau under flooded conditions) yielded very poorly. The least productive soil was the Histosol (peat), irrespective of whether it was well-drained or flooded.

Soils could be grouped according to texture, favourability of soil conditions for growth and fertility. A higher dry matter production was obtained on clayey soils than on sandier soils. The over-riding importance of a good soil physical condition over that of a high soil fertility status in encouraging dry matter production was demonstrated.

Rubber was shown to be tolerant of loose lateritic clayey soil conditions. Rubber was very sensitive to flooded soil conditions and to peat with resultant very low dry matter yields. It also responded positively to fertiliser applications and yielded poorer at lower sub-surface soil horizons.

Hevea trees have been shown to be more productive on some soils than on others. These variations can be attributed to the different physical and/or chemical properties of the soils[1].

Unfavourable soil conditions include poor soil drainage and a high water-table. Rubber performs poorly under such conditions[2], as shown when deepening of field drains led to increased yields for clone PB 86. Other poorer soil conditions, *viz.* less clay and silt contents, shallower soil depths and steeper slopes also decreased growth and yield of rubber in the field[3].

Within the genus *Hevea*, certain species have shown variable tolerances to unfavourable soil conditions. For example, Wright[4] mentioned that in the natural habitat, *Hevea spruceana* occurred on the muddy soils of the islands and river banks of the Amazon river system, which were subjected to periodic deep inundation. By comparison, *Hevea comporum* occurred on dry savannah land.

Wright[4] mentioned that *Hevea brasiliensis,* in its natural habitat, occurred on drained sites in the Amazon Basin, Brazil. Occasionally, it was present on sites subjected to brief or slight inundations. This is the sole species on which the Malaysian rubber industry is based.

Soils are spatially distributed, some may occur in distinct localities in the country. In order to study the influence of soil conditions on growth of *Hevea*, a glasshouse trial was set up. The more widespread soils present in Peninsular Malaysia were used in the study.

EXPERIMENTAL

Thirteen soils *(Table 1)* or a combination of these as other treatments, were used for the experiments. Three glasshouse experiments,

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TABLE 1 SOILS USED FOR THE EXPERIMENT

Soil	Parent material	Soil taxonomy (sub-group level)	Soil classification (FAO system)
Linau	Marine alluvium	Typic Sulfaquent	Thionic Fluvisol – saline phase
Briah	Mixed riverine/ marine alluvium	Typic Fluvaquent	Dystric Fluvisol
Chat	Argillaceous shale	Typic Kanhapludult	Ferric Acrisol
Durian	Argillaceous shale	Typic Kanhapludult	Ferric Acrisol
Serdang	Sandstone	Typic Kandiudult	Dystric Nitosol
Rengam	Granite	Typic Kandiudult	Dystric Nitosol
Harimau	Older alluvium	Typic Kandiudult	Dystric Nitosol
Kuantan	Basalt	Typic Hapludox	Orthic Ferralsol
Munchong	Argillaceous shale	Typic Hapludox	Xanthic Ferralsol
Segamat	Andesite	Rhodic Hapludox	Rhodic Ferralsol
Malacca	Argillaceous shale	Petroferric Hapludox	Xanthic Ferralsol – petric phase
Holyrood	Riverine alluvium	Xanthic Hapludox	Xanthic Ferralsol
Peat	Organic material	Hydric Troposaprist	Dystric Histosol

Experiments 1, 2 and *3,* were conducted. The experimental design was a randomised complete block design, with treatments replicated thrice in all the experiments.

Tjir 1 selfed seedlings were used as the indicator crop, at the rate of three seedlings per pot. 'Least disturbed soil samples' were collected in 20 cm diameter by 24 cm high, PVC cylindrical pots. The soil samples were collected 10 cm from the soil surface by driving the PVC pipes into the ground with a metal block and retrieving the pipes containing the soil by excavation.

In *Experiment 1*, no fertilisers or nutrient solutions were given to the seedlings during the trial. Twenty-two-day-old seedlings were used. The plants were harvested ninety-three days after transplanting when general nitrogen deficiency was beginning to appear.

In *Experiment 2*, thirty-five-day-old seedlings were used and the experiment was terminated 135 days after transplanting. During the course of the experiment, 200 ml of a complete nutrient solution[5] which contained 11.2 mg N, 3.1 mg P, 11.8 mg K, 8.0 mg Ca and 6.2 mg Mg were applied to each pot once a week. Thereafter, from the 105th day after transplanting, the same amount of nutrient solution was applied once every fourth day until the end of the experiment.

As the area where the Briah soil was collected was replanted, it was not possible to used this soil in *Experiments 2* and *3*. Additional treatments in *Experiment 2* included collecting samples of Holyrood series at different depths, 7 cm and 25 cm from the soil surface.

In *Experiment 3*, thirty-three-day-old seedlings were used and the experiment was terminated 126 days after transplanting. A granular fertiliser equivalent to Mag.Y (11% N, 10% P_2O_5, 7% K_2O, 2% MgO) was used for all the soils, except for Linau series where Mix.Y (12% N, 11% P_2O_5, 8% K_2O) considered to be more suitable was used. Ammonium sulphate, Christmas Island rock phosphate, muriate of potash and kieserite formed the constituents of the compound fertiliser treatments. In addition, two control treatments, where Munchong and Holyrood soils did not receive any fertilisers at all were included here. In the first month, 7 g of fertilisers were applied and twice this rate was used every subsequent month. The first fertiliser dosage was applied fourteen days after transplanting. For the sandier soil, like Holyrood, Harimau and Serdang series, the fertilisers were split-applied in two applications per month.

The flooded soil condition in the experiments was achieved by keeping the PVC pots in big earthern-ware pots and adding enough rain-water to maintain a water-level which was 7 cm from the soil surface. The breeding of mosquitoes was minimised by changing the water every week.

The plants in all the trials were watered sufficiently, in the morning and evening. At the end of each experiment, the whole plants, composed of all the leaves, leaf litter, stems and roots, were harvested and the dry weights determined.

At the start of the experiment, some soil samples were collected, air dried and analysed for various physico-chemical properties according to the methods outlined by Norhayati and Singh[6]. Separate samples, five for each soil, were collected from the field for oven-dry bulk density measurements.

The soil surfaces of the 'least disturbed soil' samples in the pots were measured for soil resistance by the use of a pocket soil-test penetrometer. Five measurements were taken for each pot in *Experiment 3*.

TABLE 2. AVERAGE AIR-DRY WEIGHTS AND BULK DENSITIES OF THE SOILS

Soil	Weight (kg/pot)	Air-dry bulk density (g cm^{-2})
Kuantan	7.62	0.98
Munchong	9.61	1.23
Segamat	8.43	1.08
Malacca	11.41	1.46
Holyrood	10.27	1.32
Serdang	12.31	1.58
Harimau	10.93	1.40
Rengam	11.35	1.46
Durian	11.38	1.46
Chat	7.90	1.01
Briah	9.44	1.21
Linau	6.33	0.81
Peat	1.54	0.20
Mean	9.12	1.17

RESULTS

Soil Properties

The average volume of the soil occupied by a single 'least-disturbed' core was 7800 ml. The average air-dry weights and bulk densities of the soils used are shown in *Table 2;* Serdang soil being the heaviest and peat, the lightest. Disregarding the organic soil, Linau series was the least dense.

Four Oxisols (Munchong, Segamat, Malacca, Kuantan), three Ultisols (Rengam, Durian, Chat) and two Entisols (Briah, Linau) were considered to be heavy clay-textured according to the ISSS system *(Table 3).* An Oxisol (Holyrood) and an Ultisol (Harimau) were sandy clay-textured. The texture of the Ultisol (Serdang) was sandy clay loam. Malacca series contained 40% of unconsolidated lateritic gravels on a soil weight basis.

Most of the soils studied had a low to very low soil fertility level *(Table 3)* according to an established soil fertility classification system[7]. Malacca, Munchong, Segamat, Holyrood, Serdang, Harimau and Rengam series were classified as very low in fertility while Chat, Durian and Kuantan series were classfied as low in fertility. Linau series had a very high fertility status with Briah series having a high fertility status.

The main soil structural properties and moist consistencies of the soils used for the study are given in *Table 4.* All the non-lateritic mineral soils were friable but Durian, Chat, Briah, Rengam (top 8 cm only) and Linau series when drained had a firm consistency. The friable soils also had weak to moderate medium sub-angular blocky structures.

TABLE 3. PARTICLE SIZE DISTRIBUTION, BULK DENSITY AND CHEMICAL CHARACTERISTICS OF THE SOILS

Soil	Coarse sand (%)	Fine sand (%)	Silt (%)	Clay (%)	Coarse fragments (>2 mm) wt. % of whole soil	Oven-dry bulk density (g cm^{-3})
Kuantan	2.2	16.8	26.4	54.6	—	0.93
Munchong	13.2	7.5	19.5	59.8	—	1.10
Segamat	1.5	2.5	19.9	79.1	—	0.90
Malacca	2.8	4.9	24.9	67.4	40	1.16
Holyrood	45.6	24.7	8.1	21.6	—	1.21
Serdang	47.7	35.2	2.7	14.4	—	1.17
Harimau	42.5	25.2	3.6	28.7	—	1.16
Rengam	41.6	12.1	4.6	41.7	—	1.31
Durian	6.7	12.6	34.8	45.9	—	1.29
Chat	3.6	13.3	22.6	60.5	—	1.01
Briah	0.2	2.4	34.6	62.8	—	0.99
Linau	2.4	5.6	47.8	44.2	—	1.21
Peat	—	—	—	—	—	0.2

— Not determined

TABI E 3 PARTICLE SIZE DISTRIBUTION, BULK DENSITY AND CHEMICAL CHARACTERISTICS OF THE SOILS (Contd)

Soil	pH 1 H_2O	pH 1 KCl	Org C (%)	Total N (%)	Total available P(p p m)	Acid extractable P(p p m)	Acid extractable K	Ca	Mg
							(M equiv /100 g soil)		
Kuantan	4 3	4 2	1 33	0 106	2 029	7	0 51	0 16	2 99
Munchong	4 5	4 2	1 15	0 098	599	4	0 24	0 27	0 51
Segamat	4 5	4 2	0 74	0 087	1 266	5	0 58	0 59	1 19
Malacca	4 4	4 0	1 60	0 149	492	6	0 50	0 21	1 23
Holyrood	4 8	4 4	0 66	0 070	147	4	0 49	0 09	0 72
Serdang	4 3	3 8	0 37	0 054	63	5	1 48	0 14	1 69
Harimau	4 4	4 2	0 50	0 054	53	3	0 16	0 14	0 42
Rengam	4 6	3 9	0 60	0 062	40	5	0 17	0 16	0 38
Durian	4 2	3 5	0 37	0 058	25	7	4 83	0 19	1 88
Chat	4 2	3 6	1 06	0 149	247	4	11 50	0 24	8 00
Briah	4 1	3 4	0 79	0 123	186	7	6 68	0 20	22 75
Linau	3 8	3 2	6 61	0 342	675	28	6 19	1 05	18 38
Peat	3 0	2 2	53 49	1 057	123	20	0 27	6 51	9 85

TABLE 3. PARTICLE SIZE DISTRIBUTION, BULK DENSITY AND CHEMNICAL CHARACTERISTICS OF THE SOILS (Contd.)

Soil	K	Exchangeable Ca (M-equiv/100 g soil)	Mg	Na	Base saturation (%)	CEC NH_4OAc 100 g soil
Kuantan	0.07	0.09	0.03	0.03	2.17	10.13
Munchong	0.07	0.13	0.06	0.04	4.32	6.95
Segamat	0.06	0.36	0.07	0.03	6.86	7.58
Malacca	0.09	0.19	0.09	0.03	4.04	9.90
Holyrood	0.03	0.02	0.01	0.02	2 50	3.20
Serdang	0.04	0.09	0.02	0.02	6.34	2.68
Harimau	0.03	0.08	0.01	0.03	5.81	2.58
Rengam	0.03	0.09	0.02	0.02	4.54	3.52
Durian	0.12	0.05	0.03	0.03	3.63	13.83
Chat	0.11	0.11	0.06	0.03	3.04	10.18
Briah	0.34	0.18	7.17	0.07	33.75	22.99
Linau	0.44	0.92	0.12	1.00	5.60	44.24
Peat	0.27	1.65	4.88	0.85	6.17	123.91

TABLE 4 MAIN STRUCTURAL PROPERTIES AND CONSISTENCIES OF THE SOILS

Soil	Moist consistency	Main soil structure
Kuantan	Friable	Moderate medium sub-angular blocky
Munchong	Friable	Moderate medium sub-angular blocky
Segamat	Friable	Weak medium sub-angular blocky
Malacca	Matrix with 50% loosely-packed laterites on a soil volume basis	
Holyrood	Friable	Moderate weak coarse sub-angular blocky
Serdang	Very friable	Moderate to weak medium sub-angular blocky
Harimau	Friable	Moderate medium sub-angular blocky
Rengam	Top 8 cm firm, bottom friable	Moderate strong coarse sub-angular blocky
Durian	Firm	Strong, very coarse sub-angular blocky
Chat	Firm	Moderate strong coarse sub-angular blocky
Briah	Firm	Very strong, coarse angular blocky
Linau	Sticky[a]	Moderate coarse and medium sub-angular blocky
Peat	—	Moderate fine crumbs

[a]Wet consistency but when drained, moist consistency was firm

The structure of the other soils with firm consistency ranged from moderately strong to very strong sub-angular blocky and angular blocky. The only organic soil, peat, had a moderate fine crumby structure.

The soils with firm consistency and a coarser structure e.g. Durian, Rengam, Linau (non-flooded) and Chat soils also had a high resistance to penetration by a penetrometer. Values of resistance to penetration for these soils exceeded 1.0 *(Table 5)*. The other soils had low penetrometer readings, with values of less than 1.0. Peat showed almost no resistance to penetration. The penetrability of Linau series kept with a high water-table was very low.

Total Dry Matter Production

The soils differed in their abilities to support dry matter production by plants, irrespective of whether they were fertilised or not *(Table 6)* and the differences were statistically significant *(Table 7)*. Hereafter, the dry matter yield is inferred to relate to for 'soil productivity'.

In *Experiment 1*, where plants were unfertilised, the best growth was obtained on Munchong series and the three soils with poorest growth were Linau (flooded), peat (flooded) and peat. All the plants in this experiment showed general nitrogen deficiency at about 93 days after transplanting.

When fertilisers were applied (*Experiments 2* and *3*), the plants grew for a longer period without suffering from nutrient deficiencies. In *Experiment 2*, three of the Oxisols (Kuantan, Munchong and Malacca series) continued to support high dry matter production. Peat and Linau (flooded) produced the lowest dry matter.

TABLE 5. SOIL RESISTANCE TO PENETROMETER

Soil	Penetrometer reading[a]
Kuantan	0.49
Munchong	0.35
Segamat	0.49
Malacca	Not taken
Holyrood	0.76
Serdang	0.59
Harimau	0.81
Rengam	1.38
Durian	1.54
Chat	1.07
Linau	1.14
Linau (flooded)	0.29
Peat	0
Mean	0.74

[a]Uncalibrated strength values

The other soils maintained intermediate positions in the ranking.

A lower dry matter production was obtained on Holyrood soil of depth 25–49 cm than at 7–31 cm, indicating that the lower soil horizons had poorer productivity.

In *Experiment 3,* Kuantan and Munchong soils continued to support high dry matter production while Linau series (flooded) and peat produced the lowest yields.

Fertiliser usage increased dry matter production by 44% on the clayey Munchong series and by 49% on the sandier Holyrood series.

The reductions in dry matter caused by the presence of a high water-table and by peat were more severe than that caused by low soil chemical fertility. This is evident from *Table 6,* where both Munchong (no fertiliser) and Holyrood (no fertiliser) ranked higher than Linau (flooded) and peat.

The sum of the total dry matter production for *Experiments 1, 2,* and *3* would provide the best overall picture of soil productivity since the results were based on three croppings. *Table 6* shows that the Oxisols (Kuantan, Munchong, Segamat, Malacca and Holyrood) produced more dry matter than the Ultisols (Serdang, Rengam, Chat, Durian and Harimau). Linau series (Entisol), if not flooded, ranked fourth. When it was associated with a high water-table, its productivity was the lowest among the mineral soils. Peat had the lowest productivity when both mineral and organic soils were considered.

DISCUSSION AND CONCLUSION

The results showed that there were significant yield differences between the soils which could be explained by variations in soil properties. Soil productivity is mainly influenced by four inherent soil properties *viz.* soil texture, favourable soil physical conditions for growth, chemical fertility level and soil depth. The last property was not studied in these experiments.

Figure 1 denotes the clayey soils as *C* and the sandier soils as *S*. Most of the soils were heavy clay while the sandier soils *(S)* were Holyrood, Harimau and Serdang series. Only Linau and Briah series were of high fertility *(F)* while the rest were infertile *(I)* being either low or very low in chemical fertility.

The criterion of soil structure/consistency would reflect the favourability of the soil physical conditions for growth. Soils could be grouped as poor *(P)* or unfavourable or as arable *(A)* or good. Penetrometer resistance could be used to obtain an index of tilth[8] and reflected the penetrability or compactness of a soil[9]. Based on soil profile descriptions[7], structural properties and soil consistencies *(Table 4)* supported by penetrometer readings from *Table 5*, soils with favourable soil physical conditions *(A)* were Kuantan, Munchong, Segamat, Malacca, Holyrood, Serdang, Harimau and Linau (flooded). All these soils had penetrometer readings of less than 1.0. Penetrometer readings were not taken for the lateritic soil, Malacca series, but the loose laterites within the clayey soil would infer an easy medium for root proliferation. Relatively, the other soils had poorer soil conditions for growth *(P)*.

TABLE 6. DUNCAN'S MULTIPLE RANGE TEST (5% PROTECTION LEVEL) FOR TOTAL DRY MATTER PRODUCTION (MEAN OF MEANS)

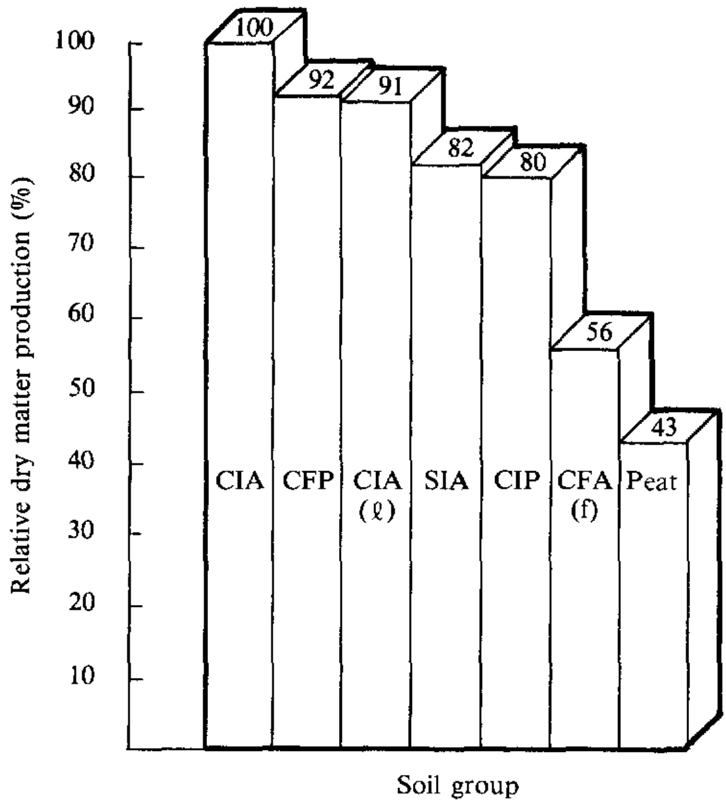
Experiment 1		Experiment 2		Experiment 3		Sum of Expt. 1, 2 and 3	
Soil	Total dry matter production (g/plant)	Soil	Total dry matter production (g/plant)	Soil	Total dry matter production (g/plant)	Soil	Total dry matter production (g/plant)
Munchong	9.00	Segamat	18.15	Linau	15.78	Kuantan	40.15
Kuantan	8.79	Kuantan	17.04	Kuantan	14.32	Munchong	37.95
Malacca	7.86	Munchong	15.98	Rengam	12.63	Segamat	36.48
Briah (flooded)	7.85	Malacca	14.84	Munchong	12.61	Linau	35.27
Durian	7.81	Holyrood (7 cm)	14.57	Chat	12.38	Malacca	34.72
Briah	7.80	Holyrood (25 cm)	14.11	Malacca	12.03	Holyrood	33.57
Segamat	7.53	Serdang	13.42	Holyrood	11.73	Serdang	32.09
Serdang	7.52	Rengam	12.40	Durian	11.22	Rengam	31.98
Harimau	7.48	Linau	12.18	Serdang	11.16	Chat	29.95
Linau	7.30	Harimau	10.96	Segamat	10.80	Durian	29.89
Holyrood	7.27	Durian	10.86	Harimau	10.03	Harimau	28.47
Chat	7.11	Chat	10.46	Munchong (unfertilised)	8.74	Linau (flooded)	21.20
Rengam	6.95	Peat	10.25	Holyrood (unfertilised)	7.87	Peat (flooded)	16.45
Linau (flooded)	6.67	Linau (flooded)	8.00	Linau (flooded)	6.53		
Peat (flooded)	4.14			Peat	2.28		
Peat	3.92						

TABLE 7. CONDENSED ANOVA TABLE FOR THE TOTAL DRY MATTER PRODUCTION OF THE VARIOUS EXPERIMENTS

Source	Experiment 1			Experiment 2			Experiment 3			Sum of Expt. 1, 2 and 3		
	df	MS	F	df	MS	F	df	MS	F	df	MS	F
Replicate	2	0.64	0.48 *ns*	2	17.07	0.98 *ns*	2	10.30	1.23 *ns*	2	18.75	1.29 *ns*
Soils	15	5.61	4.24***	13	74.58	4.28***	14	32.90	3.91**	12	129.34	8.89***
Error	30	1.33		26	17.42		28	8.38		24	14.56	
Mean (g/plant)			7.19		13.08				10.67			31.40
SD			1.15		2.41				2.90			3.82
CV (%)			16.02		18.41				27.13			12.15

ns = not significant
** = significant $P < 0.01$
*** = significant $P < 0.001$

C - Clayey
S - Sandy
F - Fertile
I - Infertile
A - Favourable soil physical conditions
P - Unfavourable soil physical conditions
f - Flooded
ℓ - Lateritic



Soils in various groups

CIA - Kuantan, Munchong, Segamat
CFP - Linau
CIA(ℓ) - Malacca
SIA - Holyrood, Serdang, Harimau
CIP - Rengam, Chat, Durian
CFA(f) - Linau (flooded)

Figure 1. Relative dry matter production of Tjir 1 on various soil groups.

Figure 1 shows that soils with high clay contents were more productive than those with low clay contents; supporting similar reported field observations[2].

When soils of different favourability of soil physical conditions, but of similar textures and chemical fertilities (*CIA* and *CIP*) were compared, the poorer soil structure/firmer consistencies resulted in a 20% reduction in dry matter production. In fact, poorer soil structure or very firm to hard soil consistencies were more important than even a low soil chemical fertility in crop reduction, as seen when *CIA* was compared to *CFP*.

Generally, rubber responded positively to a high soil nutrient status, other conditions being equal as seen when *CFP* was compared to *CIP*. Rubber was also shown to respond to fertiliser usage and to perform poorer at sub-surface horizons. Rubber also grew well on loose lateritic (40% by weight) clayey soil.

The flooding of a soil excluded oxygen from it, while carbon dioxide, hydrogen sulphide and organic acids increased to levels which were toxic to most plants[10,11]. Rubber was shown to be very sensitive to flooding, the treatment reducing dry matter production by 44%.

Rubber performed poorest on peat when dry matter production was lowered by 57%, compared to the inorganic soils. The very low productivity on peat is attributed to the combined properties such as lack of structure, higher acidity and nutrient inbalances leading to poor root development and subsequent inbalance and poorer uptake of nutrients.

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