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Diameter increment and growth of Podocarpus trees in natural forests

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SUMMARY

Stems of *Podocarpus gracilior* and *P. milanjianus* were selected at Kaptagat natural forest stands for current diameter increment assessments. Remeasurements were carried out over several growth periods. Under the local prevailing climatic conditions, *P. gracilior* showed better diameter increment than *P. milanjianus* though its periodic mean annual diameter increment of 0.34 cm is low. Lack of free growth conditions may partially explain the low rate of growth. No significant relationship was noted between initial diameter of individual trees and their corresponding mean annual diameter increment in both *podocarpus* species. Although the available data were limited, it may be tentatively concluded that for these species and such locality to reach a diameter at breast height (DBH) (OB) of 45 cm or 60 cm, *P. gracilior* requires 128 and 175 years respectively. *P. milanjianus* would require 136 and 220 years to attain the forementioned DBH (OB), respectively.

INTRODUCTION

Podocarpus gracilior Pilger and *P. milanjianus* Rendle belong to the family Podocarpaceae. While *P. gracilior* has a wide and discontinuous distribution in the drier highland forests from 1,219 to 2,740 metres above sea level, *P. milanjianus* has a wide distribution in the wetter highland forests from 2,200 to 3,050 metres above sea level in Kenya (Dale and Greenway 1961).

As a result of such wide altitudinal distribution the two species occur together and in association with other tropical species, especially the Olive and Cedar tree crops. Both species are important for timber production and are exploited in natural forests through selection system. It is important, therefore, to know their rate of growth in order to determine when exploitable diameters are reached and also to prescribe the extent of removal in natural forests.

Most of the tropical tree species do not produce distinguishable annual growth rings and it is therefore a problem to determine rates of growth of these species by counting growth rings. Rates of growth of these species in mixtures, especially in natural forests show wide variations. Factors like root competition and the position the tree occupies in the canopy, among others, cause great variations in the rate of growth.

The basic objective of the present study was to determine increments of *Podocarpus* stems in natural forest and the effect of initial diameter at breast height (DBH – OB) upon mean annual diameter increment and therefore growth rate of the two species. It should be noted that the rate of growth obtained in this study would be an indication of the rate at which trees grow in a mixture under competition for space and light. Though in the initial selection, large diameter trees were more than smaller diameter trees, a wide range of tree diameters and possibly positions of canopy have been considered in the analysis so as to represent the average rate of growth.

STUDY AREA

Two stands of natural forest forming a total of approximately 94 hectares at Masorta glade, Kaptagat forest area (0° 25′ north, 35° 35′ east) were selected for the study. The forest is on a series of more or less flat topped ridges sloping very gently from east to west and separated by forested valleys. The study tree stands in two groups on north bank of a stream with land slope of about 1 in 10 m southwards to stream bottom. At the time the study was started the vegetation was dominated by *Podocarpus* and *Olea* species (mean height 26 metres) as the top strata. Other notable species include *Teclea nobilis* Del., *Prunus africana* H.k.f. and *Cassipourea malosana* Alston.

The average elevation of the area is about 2,250 metres above sea level. Rainfall is typical of west of Rift Valley single rainfall season with an annual mean of 1,250 mm. The mean annual temperature is 15.6°C. The soils are red loam derived from volcanic basalts and tuffes.

METHODS

One hundred and eight (108) sample trees were selected in two different stands in July 1946 for measuring periodic increment in diameter at breast height. Selected trees were numbered and plotted on a plot chart. Point of measurement was also marked with a horizontal line in red paint. Only trees with cylindrical pole and no visible defects were selected for measurement. Five year measurement intervals were initially prescribed. After the 1946 establishment and subsequent diameter measurement, the sample trees were forgotten and neglected, until relocated in 1961 and paint markings found intact. After the 1961 diameter measurements further remeasurements were carried out in 1973, 1978 and 1982.

Periodic measurement for each sample tree was recorded and periodic increment determined by subtraction. Diameter classes for the measured trees were computed separately and listed against PMAI to give basic incremental trend.

To determine the effect of initial diameter (diameter at start of growth period) upon increment in diameter at breast height, several regression alaysis models of PMAI of individual trees upon their corresponding initial diameters were carried out using least squares, and polynomial regression methods (Draper and Smith 1967; Bailey 1959). Current diameter increments express the present behaviour of the stand and by relating increments to tree diameters, differences among or between species from past stand history are removed. After the regression relationships for each species at different growth periods were computed, analysis of variance were carried out in an attempt to find out the validity of regressing diameter increments on the initial diameters. The later and coefficient of determinations (R^2) were both tested for significance at probability level $p = 0.05$.

Diameter–age curves and, therefore, probable rotation ages of *Podocarpus* in the natural forest were determined by the method of Osmaston (1956). This involved arrangement of sample trees into diameter classes. Mean annual diameter increment (PMAI) during the period of growth is then determined for each class. The PMAIs are plotted on an increment diameter graph and a smooth curve carefully drown through them and it is from this that smooth PMAI are read for every diameter class and then used for further analysis. Otherwise the width of each class is divided by its PMAI giving the time taken for a mean tree to grow through that particular class. Starting from the lower limit of the lowest class as zero, the cumulative totals of times of successive classes were determined. These sub-totals correspond to the time taken by a mean tree to attain the size of successive class limits starting from the lower datum of the smallest class. These totals are then plotted on a graph of diameter-cumulative times of passage (age) to give smoothed curves showing the general trend of growth. A separate estimate of the time or age at which the mean tree enters the lowest diameter class from establishment is made with the aid of periodic mean annual increment of the lowest diameter class. This estimate enables an extension of the lower end of the curves and a complete estimate of the possible full rotation of the species.

RESULTS

Table 1 and 2 show basic data on periodic growth of *P. gracilior* and *P. milanjianus* respectively. Selected study stems ranged in DBH (OB) from 15 cm to over 120 cm for *P. gracilior* and from 15 cm to 95 cm for *P. milanjianus*. In both species periodic annual increment in diameter at various diameter classes are low. While earlier growth periods showed almost equal mean increment for both species, *P. milanjianus* is seen to slow down in diameter increment as the stand build up in basal area. In both species periodic diameter increment show wide variations. Observed coefficient of variation in diameter increments is lower in earlier growth periods with *P. gracilior* but is seen to increase at later age to be in level with the almost constant but higher increment variation in *P. milanjianus*.

Several models of multiple regression analysis using raw and logarithmic transformed data did not yield significant relationships at various growth periods. Further analysis was attempted with polynomial regression analysis at three orders up to cubic relationship. For each species two growth periods were considered in the computation. In both species no significant relationship was observed between individual tree initial diameters and corresponding diameter increments over the two growth periods considered. Figure 1 (a) and (b) shows a scatter diagram of the above relationship. For *P. glacilior,* quadratic and cubic relationship equations (R^2) explained only 21% and 28% variation respectively of the initial diameter upon mean annual increment. Similarly, only 31% and 33% variation was explained by the *P. milanjianus* equations respectively. As in the above results (tables 1 and 2) where large coefficient of variations were observed on the increments of the two species, lack of growth parameter correlations may again be attributed to complex interaction among the particular species present in the mixed uneven age natural forest stands which may in turn result in limited and marked variation in freedom of growth.

By listing periodic annual increments against 10 cm diameter classes, scatter graphs of diameter versus corresponding diameter increments were produced. Smoothening increment values in the graph produced average diameter increment over a wide range of diameter classes as shown in table 3 for *P. gracilior* and table 4 for *P. milanjianus*. Time of passage through each diameter class and mean time of passage in years are also shown for each species.

From the mean time of passage in years a graph on diameter-age curves for both species is produced in figure 2. It is observed that under the prevailing conditions of mixed natural forest stand and limited free growth at Kaptagat and similar sites, *Podocarpus gracilior* may be expected to attain 45 cm and 60 cm DBH (OB) in 128 and 175 years respectively. Under similar average growth conditions it would take *P. milanjianus* about 136 years to attain 45 cm and 220 years to attain 60 cm DBH (OB).

Table 1. Diameter increment of *Podocarpus gracilior* in natural forest at Kaptagat

Diameter classes (cm)	1946 — 1961 PMAI	1961 No. of trees	1961 — 1973 PMAI	1973 No. of trees	1973 — 1978 PMAI	1978 No. of trees	1946 — 1978 Increment	1978 PMAI
20	0.38	4	. . .	. . .	. . .	. . .	. . .	. . .
25	0.46	5	0.38	. . .	. . .	. . .	. . .	. . .
30	0.22	4	0.35	5	0.36	5	5.47	0.17
35	0.17	1	0.25	4	0.09	4	2.90	0.09
40	0.24	3	0.16	2	0.47	4	4.35	0.14
45	0.38	4	0.13	1	0.13	2	11.77	0.37
50	0.39	5	0.22	5	0.15	3	10.34	0.32
55	0.29	7	0.26	6	0.23	4	9.73	0.30
60	0.36	11	0.28	8	0.24	5	10.22	0.32
65	0.30	6	0.29	7	0.31	7	10.06	0.31
70	0.23	8	0.38	10	0.22	12	7.30	0.23
75	0.15	2	0.14	7	0.21	9	4.15	0.13
80	0.29	4	0.54	2	0.32	5	10.15	0.32
85	0.33	9	0.18	4	0.18	2	10.50	0.33
90	0.37	5	0.28	8	0.13	6	10.10	0.32
95	0.56	1	0.31	4	0.31	5	5.49	0.17
100	0.22	3	0.14	3	0.37	6	4.45	0.14
105	0.42	3	0.13	1	0.16	3	14.30	0.45
110	. . .	. . .	0.34	2	0.00	1	. . .	. . .
115	0.32	2	0.72	1	0.52	1	8.25	0.26
120	0.32	3	0.26	2	0.41	1	8.70	0.27
Mean increment	0.32		0.29		0.25			0.29
SD	0.10		0.15		0.14			0.10
CV (%)	31		50		54			36

SD = standard error
CV = coefficient of variation
PMAI =

Table 2. Diameter increment of *Podocarpus milanjianus* in natural forest at Kaptagat

Diameter classes (cm)	1946 PMAI	1961 No. of trees	1961 PMAI	1973 No. of trees	1973 PMAI	1978 No. of trees	1946 — 1978 Increment	1978 PMAI
10	0.46	3	. . .	. . .	. . .	. . .	. . .	. . .
20	0.28	2	0.36	4	0.21	3	12.2	0.41
30	0.30	4	0.19	1	0.18	2	6.1	0.19
40	0.20	1	0.20	5	0.11	4	8.2	0.26
50	0.22	1	0.17	1	0.18	2	7.1	0.22
60	0.15	1	0.21	1	. . .	. . .	5.5	0.17
70	. . .	. . .	. . .	. . .	0.14	1	. . .	. . .
80	0.61	1	. . .	. . .	. . .	. . .	14.7	0.46
90	. . .	. . .	0.48	1	0.00	1	. . .	. . .
Mean increment	0.32		0.25		0.14			0.29
SD	0.16		0.12		0.08			0.11
CV (%)	51		50		54			38

SD = standard deviation CV = coefficient of variation PMAI =

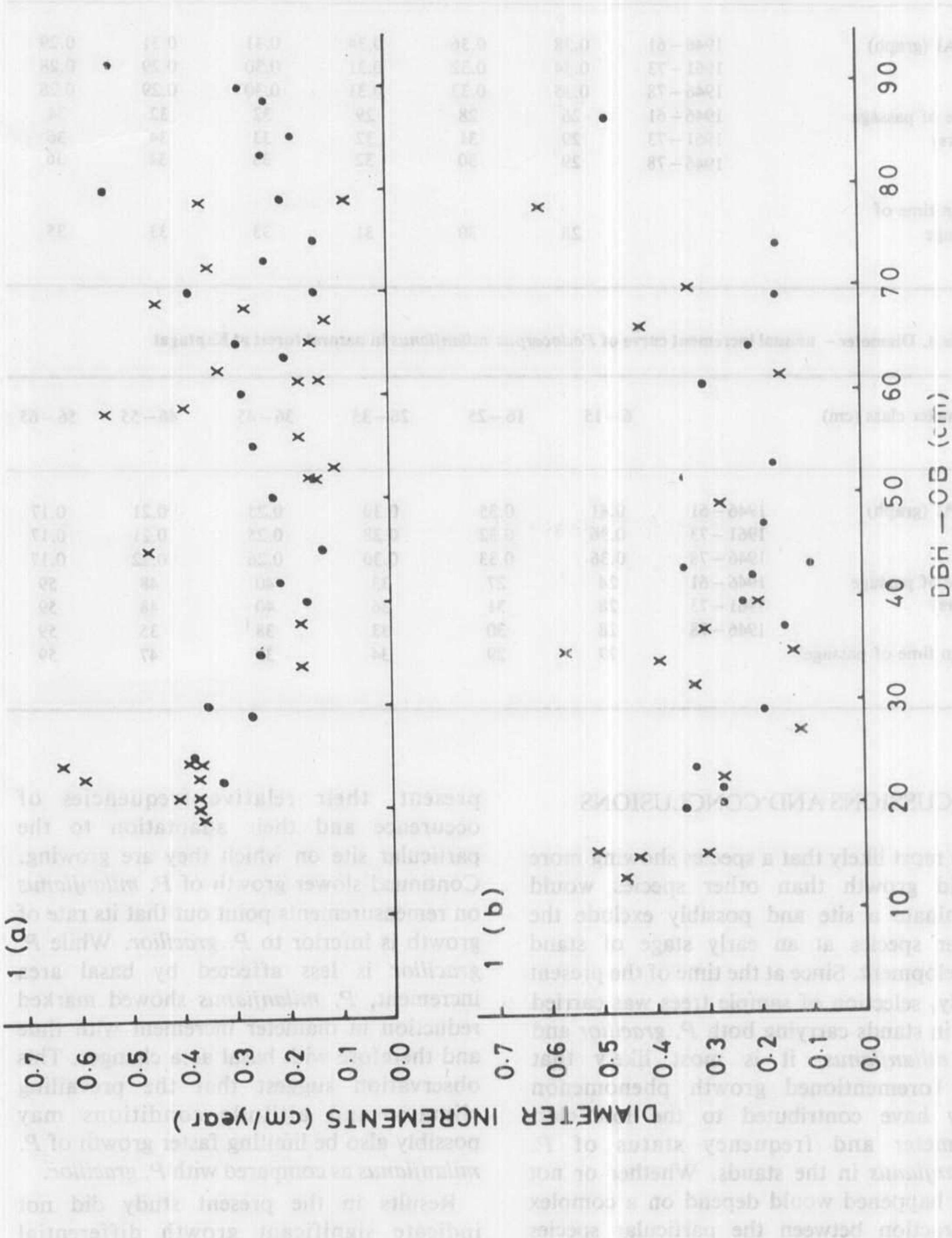

Figure 1. Two growth period relationships between initial tree diameter and diameter increment of *P. gracilior* (a) and *P. milanjianus* (b) in natural forest

Table 3. Diameter – annual increment curves of *Podocarpus gracilior* in natural forest at Kaptagat

Diameter class (cm)		16 – 25	26 – 35	36 – 45	46 – 55	56 – 65	66 – 75
PMAI (graph)	1946 – 61	0.38	0.36	0.34	0.31	0.31	0.29
	1961 – 73	0.34	0.32	0.31	0.30	0.29	0.28
	1946 – 78	0.35	0.33	0.31	0.30	0.29	0.28
Time of passage (years)	1946 – 61	26	28	29	32	32	34
	1961 – 73	29	31	32	33	34	36
	1946 – 78	29	30	32	33	34	36
Mean time of passage		28	30	31	33	33	35

Table 4. Diameter – annual increment curve of *Podocarpus milanjianus* in natural forest at Kaptagat

Diameter class (cm)		6 – 15	16 – 25	26 – 35	36 – 45	46 – 55	56 – 65
PMAI (graph)	1946 – 61	0.41	0.35	0.30	0.25	0.21	0.17
	1961 – 73	0.36	0.32	0.28	0.25	0.21	0.17
	1946 – 78	0.36	0.33	0.30	0.26	0.22	0.17
Time of passage (years)	1946 – 61	24	27	33	40	48	59
	1961 – 73	28	31	36	40	48	59
	1946 – 78	28	30	33	38	35	59
Mean time of passage		27	29	34	39	47	59

DISCUSSIONS AND CONCLUSIONS

It is most likely that a species showing more rapid growth than other species would dominate a site and possibly exclude the other species at an early stage of stand development. Since at the time of the present study, selection of sample trees was carried out in stands carrying both *P. gracilior* and *P. milanjianus*, it is most likely that the forementioned growth phenomenon may have contributed to the low class diameter and frequency status of *P. milanjianus* in the stands. Whether or not this happened would depend on a complex interaction between the particular species present, their relative frequencies of occurence and their adaptation to the particular site on which they are growing. Continued slower growth of *P. milanjianus* on remeasurements point out that its rate of growth is inferior to *P. gracilior*. While *P. gracilior* is less affected by basal area increment, *P. milanjianus* showed marked reduction in diameter increment with time and therefore with basal area changes. This observation suggest that the prevailing climatic and altitude conditions may possibly also be limiting faster growth of *P. milanjianus* as compared with *P. gracilior*.

Results in the present study did not indicate significant growth differential

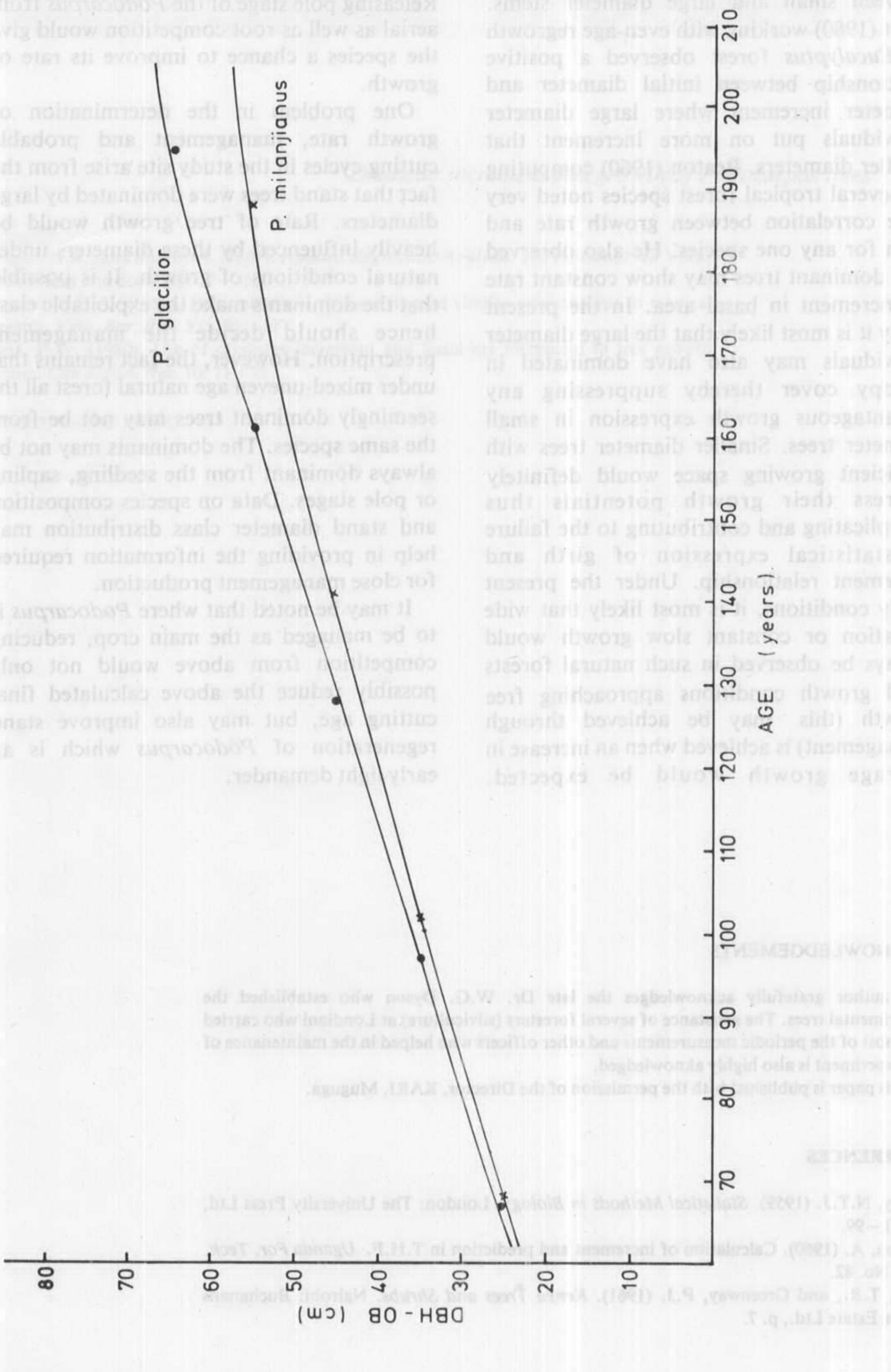

Figure 2. Diameter-age curve of *P. gracilior* and *P. milanjianus* in natural forest

between small and large diameter stems. West (1980) working with even-age regrowth of *Eucalyptus* forest observed a positive relationship between initial diameter and diameter increment where large diameter individuals put on more increment than smaller diameters. [illegible] on several tropical forest species noted very little correlation between growth rate and girth for any one species. He also observed that dominant trees may show constant rate of increment in basal area [illegible] study it is most likely that the large diameter individuals may also have dominated in canopy cover thereby suppressing any advantageous growth expression in small diameter trees. Smaller diameter trees with sufficient growing space would definitely express their growth potentials thus compensating and contributing to the failure in statistical expression of girth and increment relationship. Under the present study conditions, it is most likely that wide variation or constant slow growth would always be observed in such natural forests until growth conditions approaching free growth (this may be achieved through management) is achieved when an increase in average growth would be expected.

Releasing pole stage of the *Podocarpus* from aerial as well as root competition would give the species a chance to improve its rate of growth.

One problem in the determination of growth rate, management and [illegible] [illegible] in the study site arose from the fact that stand trees were dominated by large diameters. Rate of tree growth [illegible] [illegible] [illegible] natural [illegible] [illegible] hence should [illegible] prescription [illegible] under mixed uneven age natural forest all the seemingly dominant trees may not be the same species. The dominants may not be always dominant from the seedling, sapling or pole stages. Data on species composition and stand diameter class distribution may help in providing the silviculture regimes for close management production.

It may be noted that where *Podocarpus* is to be managed as the main crop, reducing competition from above would not only possible reduce the [illegible] [illegible] of final cutting size, but may also improve initial regeneration of *Podocarpus* which is an early [illegible] [illegible].

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