

GR/MLT.

17th October, 1962.

Prof. T.A. Davis,
Indian Statistical Institute,
203 Barrackpore Trunk Road,
CALCUTTA 35, INDIA.

Dear Prof. Davis,

During the past two months I have been in America. Upon my return I found your letter of the 24th September and enclosure awaiting me. Thank you for this interesting article. I have taken the liberty of doing a few manipulations with data of your table 15 as shown on my table attached hereto. Reference is by your numbers 1 through 33. In order to fix position I have arbitrarily chosen from a map an important town. The other column headings are self explanatory.

First, I plotted $(L-R)/(L+R)$ versus geographic longitude. Points at $+0.25$, 110° and -0.25 , 130° were arbitrarily selected and connected by a dashed line. This seemed a reasonable approximation to a least squares solution for the data. Longitudes 290° and 110° are where the geomagnetic equator is farthest from geographic equator.

Second, I plotted $(L-R)/(L+R)$ versus geomagnetic latitude. An arbitrary dashed line was drawn in by eye at a slope of $0.004 (L-R)/(L+R)$ per degree latitude. This seemed like a reasonable approximation to the data.

Third, I plotted $(L-R)/(L+R)$ versus magnetic field inclination. An arbitrary dashed line was drawn in by eye at a slope of $0.0012(L-R)/(L+R)$ per degree inclination. This again, seemed like a reasonable approximation to the data.

Fourth, I plotted $(L-R)/(L+R)$ versus geographic latitude. The best dashed line, by eye, appears to follow $(L-R)/(L+R) = 0$ independent of latitude.

These four graphs are enclosed.

Apparently your palm trees are quite different from my beans. The beans have a very strongly inbuilt preference for direction of turning. The palm has no preference. Direction is determined by some chance factor which is mainly random but slightly influenced by the earth's magnetic field. Examination of the east/west effect of cosmic rays produced no hint that this phenomenon was a cause. The direction of leaf spiral seems most likely determined at time of fertilization or germination. I believe you are on to a subject of considerable importance. However, it would be well to secure more data of good quality on $(L-R)/(L+R)$ from higher magnetic latitudes near geographic longitudes of 290° and 110° .

On the basis of your findings on *Cocos Nucifera* it seems worthwhile for me to have another go at *Brodiaea Volubilis* and Macquarie Vine. Perhaps you can find some other plant which exhibits random direction of spiral structure? You may use any of the above as you see fit. My article on beans was in *Castanea*, December, 1960. These experiments were done at Green Bank, West Virginia, U.S.A. during summer of 1959. Please correct my initial.

Thanking you for keeping me advised of your work, I am

Sincerely yours,

Grote Reber.

Position	L-R	Place Name	Geographic		Geomagnetic		Compass Inclination
	L+R		E. Long.	Lat.	E. Long.	Lat.	
1	-.064	Tongataba	185	21S	258	-24	-42
2	+.032	Tutuila	189	14S	262	-16	-31
3	-.040	Apia	188	14S	262	-16	-30
4	-.108	Suva	178	18S	253	-23	-40
5	+.060	Vila	168	18S	241	-24	-42
6	-.215	Noumea	166	22S	240	-28	-48
7	-.052	Tatamba	160	8S	231	-15	-27
8	-.054	Rabaul	152	4S	222	-13	-21
9	+.010	Port Moresby	147	9S	218	-18	-30
10	+.088	Hollandia	141	3S	211	-13	-21
11	-.032	Manila	121	15N	190	+4	+16
12	-.153	Beluran	118	6N	187	-5	-6
13	-.083	Kuching	110	2N	179	-9	-15
14	+.107	Baria	107	10N	176	-1	+3
15	+.088	Kuala Lumpur	102	3N	171	-8	-16
16	-.278	Port Blain	93	12N	162	+1	+7
17	+.004	Texpur	93	27N	163	+16	+39
18	-.080	Dacca	90	24N	160	+13	+33
19	-.009	Columbo	80	7S	148	-17	-36
20	+.040	Cuttack	86	21N	156	+11	+27
21	+.059	Madras	80	13N	150	+3	+10
22	+.028	Madurai	78	10N	148	0	+3
23	+.053	Mangalore	75	13N	145	+4	+11
24	-.118	Mauritius	58	20S	123	-27	-54
25	+.061	Zanzibar	39	6S	106	-10	-36
26	+.112	Ibadan	4	8N	75	+11	-5
27	+.010	Lome	2	6N	73	+10	-8
28	+.010	Accra	0	6N	71	+10	-7
29	-.046	Abidjan	356	5N	66	+10	-9
30	+.023	Freetown	347	8N	58	+15	+4
31	+.173	Paramaribo	305	6N	15	+17	+35
32	+.270	Georgetown	302	7N	11	+18	+38
33	+.026	Kingston	283	18N	351	+29	+52

"Description of the Earth's Main Magnetic Field and its
 Secular Change 1905-1945" Tuve and Fleming, D.T.M., C.I.W.
 Publication No. 578; 1948
 Field for 1945 as tabulated.

Geomagnetic Latitude, pages 28-33
 Geomagnetic Longitude, pages 34-39
 Inclination pages 454-461

Position a	c (<u> </u>) Place Name	d Geographic		f Geomagnetic			h Compass		b L-R L+R
		East Long.	Lat.	East Long	Lat.	Geomag. Geograph.	Inclination	X F Gauss	
1	(Tongatapu) Tonga Islands	185E	21S	258	-24	-3	-42	.446	-0.064
2	(Tutuila) American Samoa	189E	14S	262	-16	-2	-31	.402	+0.032
3	(Apia) Western Samoa	188E	14S	262	-16	-2	-30	.400	-0.040
4	(Suva) Fiji Islands	178E	18S	253	-23	-5	-40	.442	-0.108
5	(Vifa) New Hebrides	168E	18S	241	-24	-6	-42	.460	+0.060
6	(Noumea) New Caledonia	166E	22S	240	-28	-6	-48	.485	-0.215
7	(Tatambai) Br. Solomon	160E	8S	231	-15	-7	-27	.405	-0.052
8	(Rabaul) Trust Terr. Is.	152E	4S	222	-13	-9	-21	.387	-0.054
9	(Port Moresby) Papua & N. Guinea	147E	9S	218	-18	-9	-30	.415	+0.010
10	(Hollandia) Neth. N. Guinea	141E	3S	211	-13	-10	-21	.392	+0.088
11	(Manila) Philippines	121E	15N	190	+4	-11	+16	.400	-0.032
12	(Beluran) North Borneo	118E	6N	187	-5	-11	-6	.398	-0.153
13	(Kuching) Sarawak	110E	2N	179	-9	-11	-15	.411	-0.083
14	(Baria) South Vietnam	107E	10N	176	-1	-11	+3	.406	+0.107
15	(Kuala Lumpur) Malaya	102E	3N	171	-8	-11	-16	.412	+0.088
16	(Port Blair) Andaman Islands	93E	12N	162	+1	-11	+7	.410	-0.278
17	(Tezpur) Assam India	93E	27N	163	+16	-11	+39	.475	+0.004
18	(Dacca) East Pakistan	90E	24N	160	+13	-11	+33	.455	-0.080
19	(Columbo) Ceylon	80E	7S	148	-17	-10	-36	.418	-0.009
20	(Cuttack) Orissa, India	86E	21N	156	+11	-10	+27	.445	+0.040
21	(Madras) Madras, India	80E	13N	150	+3	-10	+10	.400	+0.059
22	(Madurai) Kerala, India	78E	10N	148	0	-10	+3	.392	+0.028

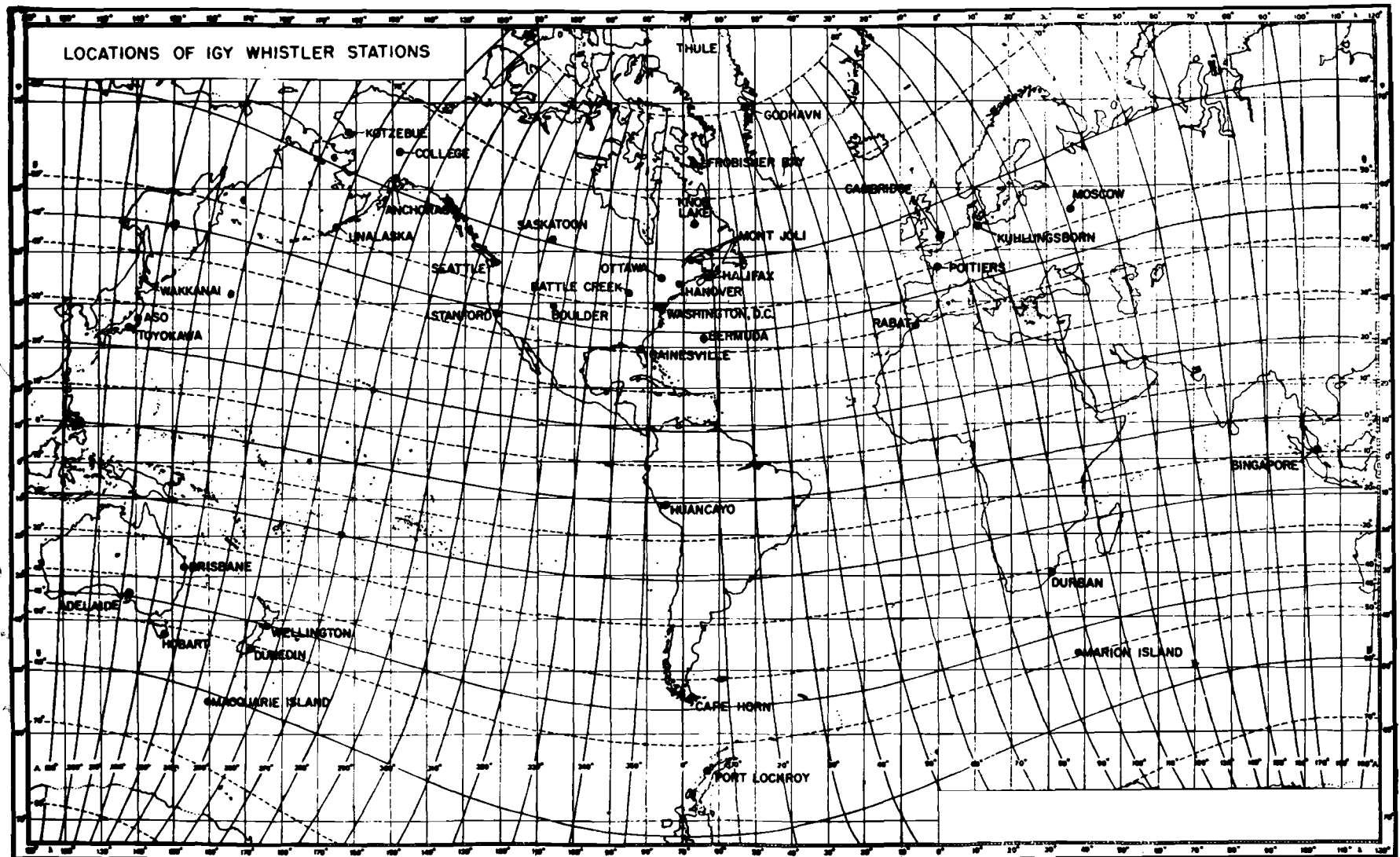


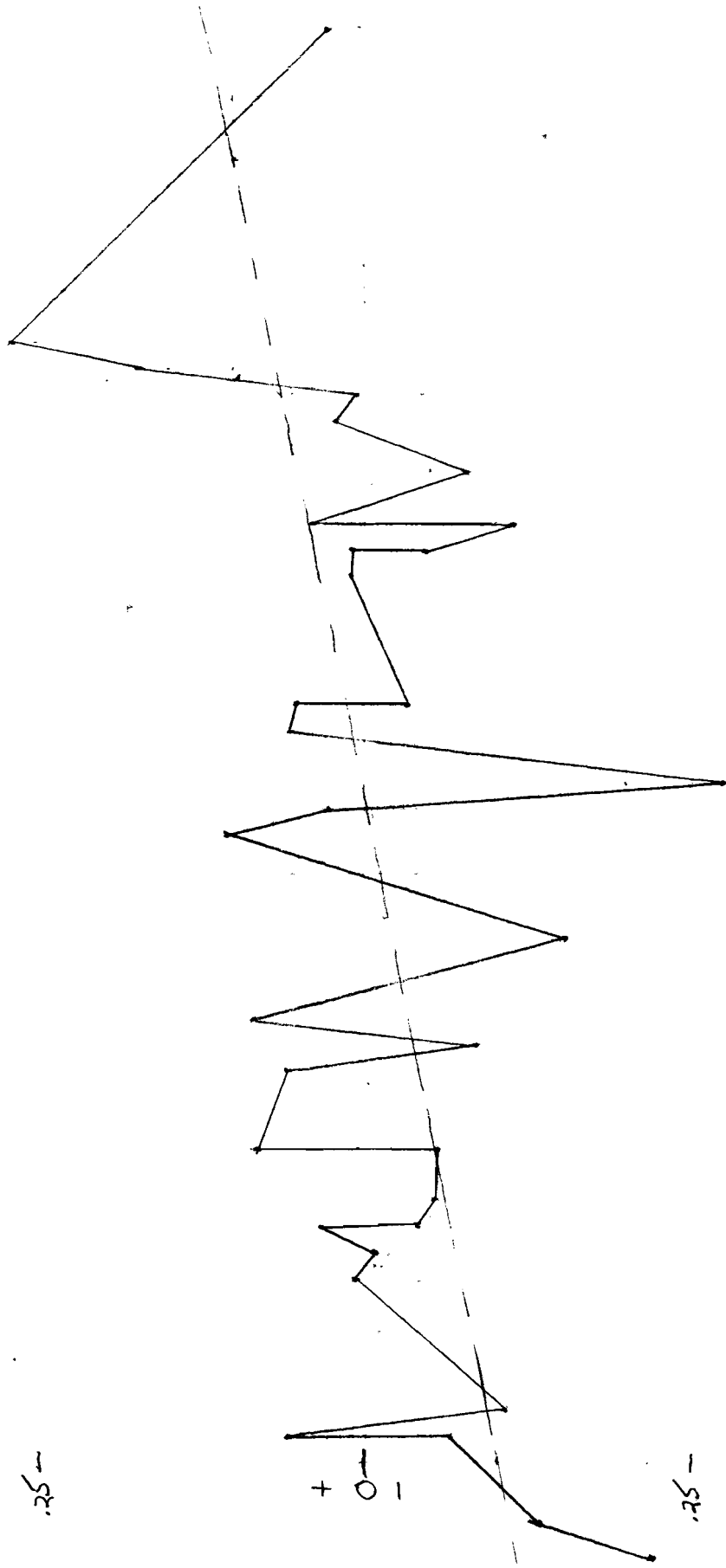
Fig. 5—Map showing locations of IGY whistler stations. Curved lines are geomagnetic coordinates.

$$\frac{(L-R)}{(L+R)}$$

.25-

+
O
-

.25-

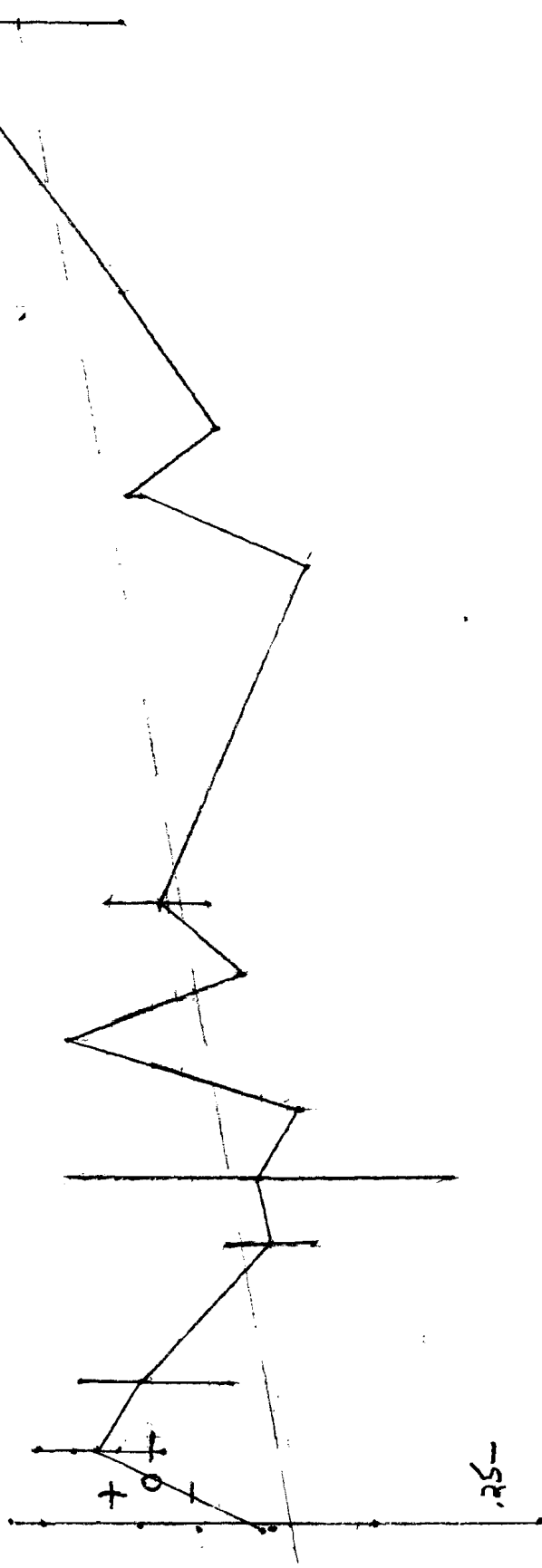


S 25 20 15 10 5 0 5 10 15 20 25 N

Geomagnetic latitude

$$\frac{(L-R)}{(L+R)}$$

.25-



.25-

10

5

-0+

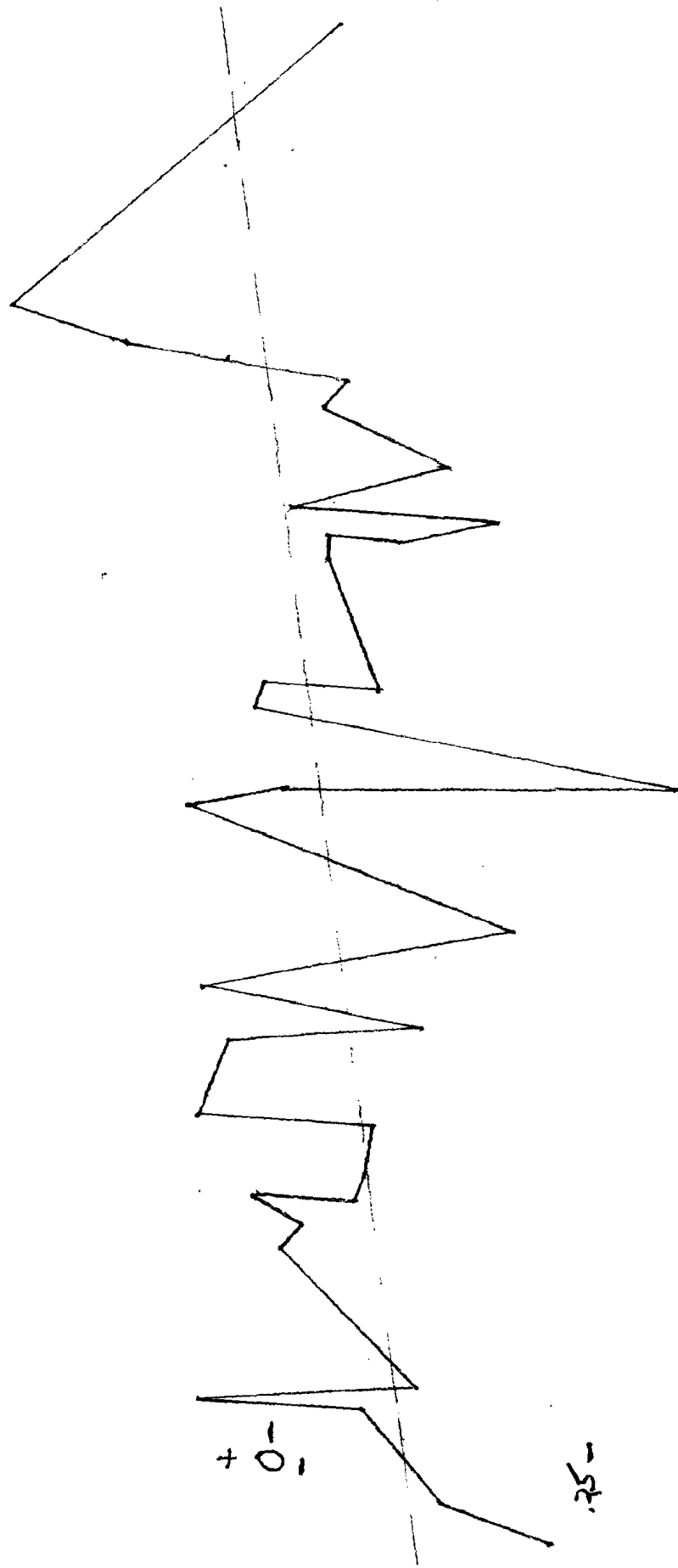
5

10

(Geomagnetic - Geographic) latitude

$$\frac{(L-R)}{(L+R)}$$

.75-



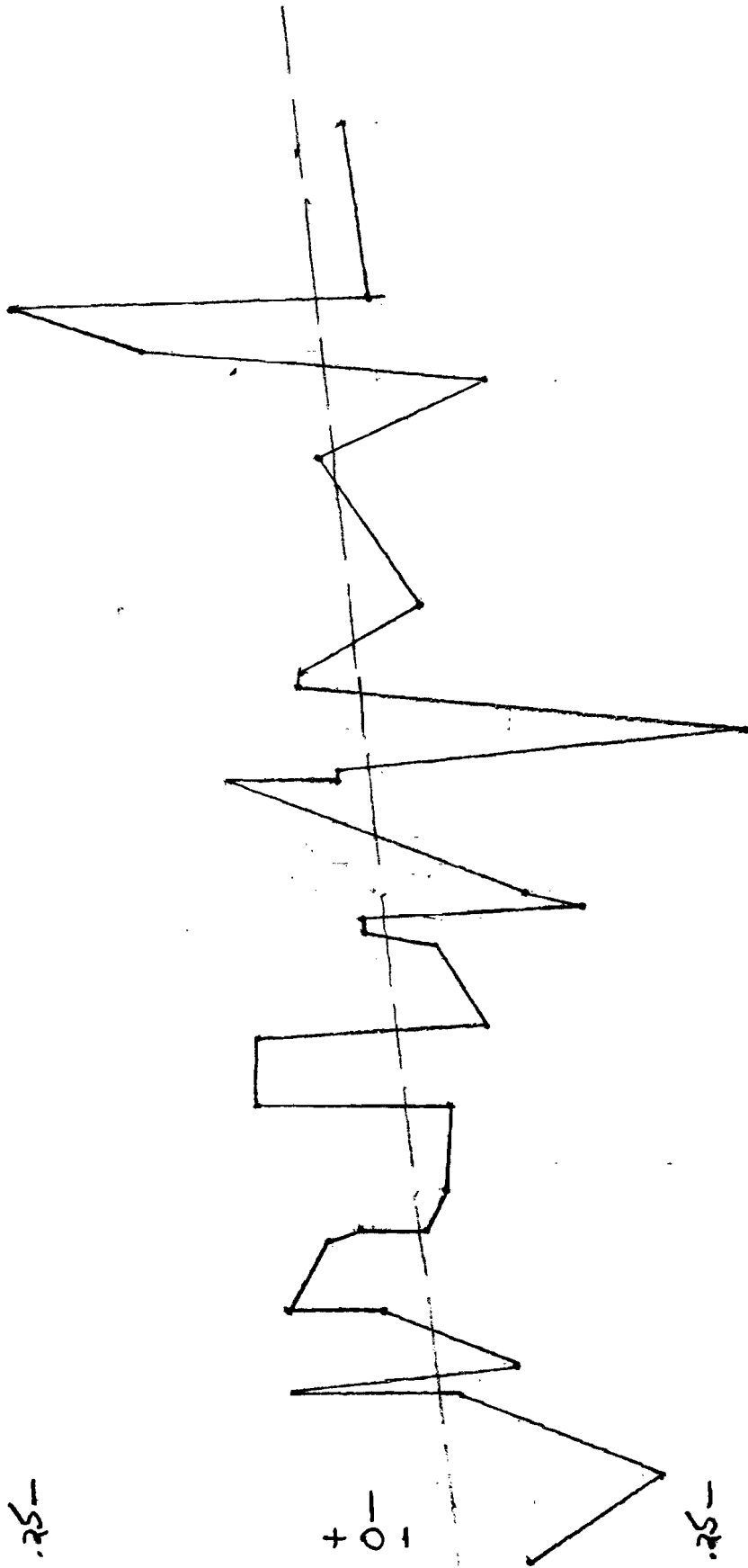
S 25 20 15 10 5 0 5 10 15 20 25 N
Geomagnetic Latitude

$$\frac{(L-R)}{(L+R)}$$

.25-

+
0
-

.25-



50 40 30 20 10 - 0 + 10 20 30 40 50

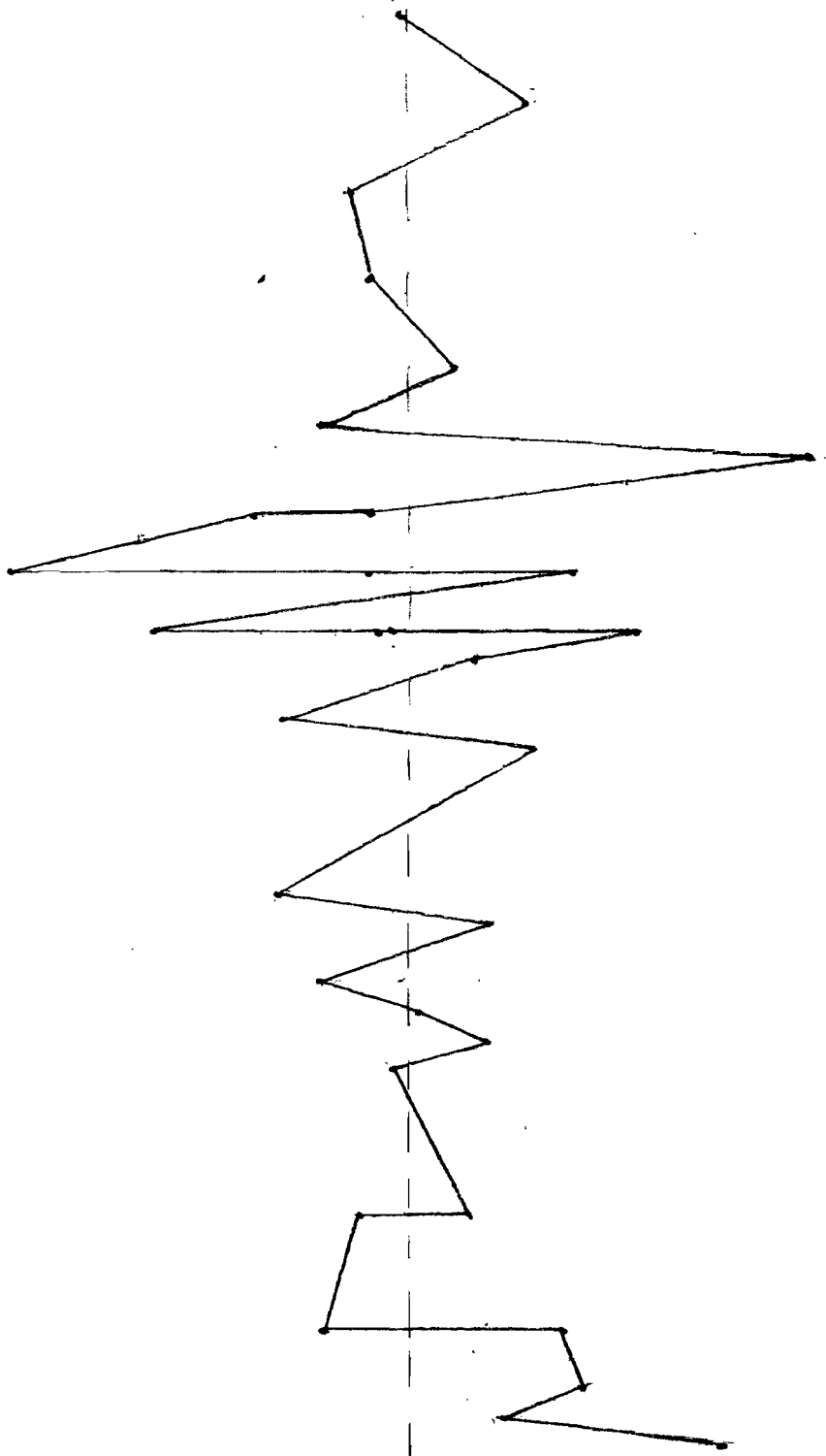
Magnetic Field Inclination

$$\frac{(L-R)}{(L+R)}$$

.25-

+ 0 -

.25-



S 20 15 10 5 0 5 10 15 20 25 N

Geographic Latitude

Asymmetry and Yield in *Cocos nucifera* L.

The leaves of *Cocos nucifera* L. are arranged in a right-handed or left-handed spiral, the angle between corresponding leaves in successive whorls being about 30°. The frequency of lefts among 3028 trees in India was 52.05% (DAVIS¹) and among 13 842 trees elsewhere it was 52.90%. The asymmetry is not inherited (DAVIS¹) and has been regarded as trivial.

Of the 384 trees used at the Central Coconut Research Station, Kayangulam, Kerala (India), for trials of micro-nutrients, 177 were left-spiralled. They were divided into three groups, healthy, moderately affected by a major Root (wilt) disease, and severely affected. The mean number of nuts per year borne by the right-spiralled and left-spiralled trees in these groups between 1955 and 1960 inclusive are shown in the Table.

The figures for the healthy trees give $t = 2.721$ (126 degrees of freedom). The probability for a difference of that magnitude or more being small ($P = 0.0076$), the assumption that left-spiralled trees give higher yields is strongly substantiated. The figures for the diseased trees, though not quite significantly different, strongly reinforce the significance of those for the healthy trees.

As neither the nuts nor the kernels from the two types of trees were weighed separately, it is, of course, possible that the total mean weight of copra produced by the left-spiralled trees was not greater than that from the right-spiralled. Nor is it claimed that all races of coconut, in all soils and climates, behave in this way. However, the

Average number of nuts produced per tree per year

Condition of trees	No. of trees		Nuts per tree/year	
	right	left	right	left
Healthy	70	58	53.93	65.25
Moderate disease	67	61	32.60	35.98
Severe disease	70	58	18.58	23.15

biological fact here presented is, I believe, novel. Many explanations can be suggested for it, of which I hope to discuss some elsewhere².

Zusammenfassung. Die Blätter der Kokospalme (*Cocos nucifera* L.) sind in links- oder rechtsdrehenden Spiralen angeordnet. Zählungen an einem grossen Material indischer und nichtindischer Palmen (3028 bzw. 13 842 Bäume) ergab ein geringfügiges Überwiegen der linksdrehenden Blattspiralen (52,05% bzw. 52,90%). Der Drehsinn der Spiralen erwies sich, wie Kreuzungsversuche zeigten, als genetisch nicht fixiert. In fünfjährigem Feldversuch (1955–1960) lieferten Palmen mit linksdrehenden Blattspiralen einen signifikant grösseren Ertrag an Kokosnüssen.

T. A. DAVIS

Biometric Research Unit, Indian Statistical Institute, Calcutta (India), March 5, 1962.

¹ T. A. DAVIS, *J. Genet.*, 58, 42 (1962).

² Help received from the Indian Central Coconut Committee for my service is gratefully acknowledged.