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ANNALS

OF THE

ROYAL BOTANIC GARDENS, PERADENIYA.

EDITED BY

HERBERT WRIGHT, A.R.C.S., F.L.S.

LATELY ACTING DIRECTOR.

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The publication of this number has been seriously delayed, not by lack of material, but on account of the serious accident that befel Dr. Willis last March. It should have appeared in May. The next number will appear after as short an interval as possible.

Studies in Plant Breeding in the Tropics.

BY

R. H. LOCK.

(Fellow and late Frank Smart Student of Gonville and Caius College, Cambridge.

II.—*EXPERIMENTS WITH PEAS.*

CONTENTS.

Introduction: Climate and acclimatization. Methods.
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Summary.

IN a previous communication to these Annals* some account was given of those recent advances in our understanding of the physiology of inheritance which have been derived from studies in the cross-breeding of plants; and in the same paper was embodied a preliminary description of certain experiments carried out by the writer, which form a contribution to the same subject. It remains to set forth a more complete account of the observations already

* Page 299, Annals of the Royal Botanic Gardens, Peradeniya, Vol. II., Part II., August, 1904.

partly announced, and to add to the number some further experiments which bear in the same direction.

The object of these experiments was two-fold. They were designed in the first place to test the conclusions of Mendel and of those other botanists who in recent years have extended and confirmed his observations ; and they were also undertaken with a view to applying these theoretical principles to the practical processes of plant breeding. To this attempt was added a special interest from the fact that it was to be made in a tropical country, under circumstances in which very little work of this kind had been previously carried out.

At the outset attempts were made to effect cross-fertilization between varieties of a considerable number of different species of plants, some of them natives of the tropics and others introduced from a temperate region. Many of these attempts met with only partial success, as indeed was to have been expected, and others were quite unsuccessful. Including all the cases of plants from which fertile offspring were obtained by crossing, a considerably larger number of experiments was begun than could have been completed if all had progressed without misfortune. But the progress of the work met with a variety of difficulties ; and furthermore, the surviving cross-bred plants underwent a kind of natural selection, the losses being determined by such factors as an unfavourable climate, a want of experience of the best conditions of growth, the attacks of fungi, insect pests, and the like. In the end the experiments with Indian corn and with peas were found to be the only ones which yielded results of any importance. In the present instalment I shall confine myself to an account of the evidence derived from peas.

In the case of experiments with peas, Mendel's own results, as well as a number of more recent observations, could be put to a practical test. In work of this kind, if it is desired to pass beyond the stage of merely confirmatory experiments, it is often necessary at the outset to make crosses more or less at random between such forms as may be at hand, in the hope that some of the results will afford interesting exceptions to the ordinary routine of Mendelian experience. And the work of the practical breeder must usually have its beginning in similar speculative experiments ; since from the present state of our knowledge no one can foretell with any degree of certainty the result of a particular cross which has not been previously made. Indeed, one of the chief aims of this class of experimental work is the attainment of a system of knowledge which will in some degree enable us to foretell the results of new combinations ; but this stage of the inquiry is still far from being realized. The accurate prediction of phenomena is one of the most important effects of all classes of codified scientific knowledge, and there can be no doubt that in the case of the present branch of physiology a similar degree of cognition is attainable ; indeed, the advance in this direction has already been one of phenomenal rapidity.

Theoretical reasons led me to select the following strains of *Pisum sativum* for particular study. The pea Telephone was chosen for examination owing to its alleged erratic and exceptional behaviour on crossing. Telegraph, a form nearly allied to Telephone, has been regarded as showing rather less irregularity. As a fresh specific test of these forms they were crossed with a smooth yellow seeded pea commonly grown by natives in Ceylon. For studying the colour characters of the testa, a large " French Sugar Pea " was made use of ;* and also a form of *Pisum arvense* of very primitive appearance, and closely similar to one which is known to the natives of Northern India as Chota matar, but which is only rarely grown in Ceylon.

From a practical point of view the method adopted was to grow a series of good European varieties of peas and to cross those which flourished best under the new conditions both with each other and with varieties obtained locally. As large a number as possible of the offspring of these crosses was then grown, and the progeny which showed the best combinations of characters were picked out for further propagation.

* Identical, it appears, with the " Purple Sugar Pea " described by Bateson.

A method which deserves particular emphasis is one which has yielded valuable results in the hands of De Vries, and consists in deducing the character of a particular plant—whether originating in a cross or otherwise—from a study of its offspring by self-fertilization. For this purpose all the seeds of the plant under examination should if possible be sown; but in cases where these are too numerous, at least a considerable sample. The nature, or Mendelian constitution, of any particular cross-bred plant can in this way be deduced, sometimes from the examination of one, or as a general rule of at the most three generations. This method is particularly applicable in a climate under which as many as three generations can be grown in a single year.

In addition to this work on crossing, the writer also attempted some experiments in definite selection on lines similar to those recently described by Johannsen; one of the characters examined being the size of individual pea seeds. These attempts were given up however owing to the apparent impossibility of arriving at anything approaching to uniform conditions between plant and plant, or between generation and generation. The latter difficulty was perhaps the more serious of the two, owing to differences in the rainfall and other conditions of climate at different times of year. In order to carry out such an experiment properly, only one generation must be grown each year, and further, the sowing should take place each year at a corresponding season. But the differences apparently caused by irregularities of nutrition in a potentially uniform batch of seedlings were also sometimes astonishing; and it was found most difficult to obtain an even preparation of soil in the seed beds by native assistance, even under the closest personal supervision. This difficulty would appear to be a fundamental one in all exact experiments of this kind, and renders such work of little value unless carried out on a very large scale for many generations, in order that accidental differences of soil, &c., may become equalized. Moreover the crop obtained from uncrossed strains of peas was very small at the best of times, and when the conditions were unfavourable it became almost nothing. In such circumstances it was thought better to confine the attention to observing the behaviour of the more definite characters on crossing.

CLIMATIC CONDITIONS—ACCLIMATIZATION.

The most important differences in climate between different parts of the year in Ceylon depend especially upon variations in the amount of precipitation. Thus a general idea of these differences, so far as they affect the growth of plants, may best be obtained from a table of the monthly rainfall. Such a table is given below, and covers the period during which the work in Ceylon was carried on.

Rainfall at Peradeniya in Inches, and Number of Rainy Days.

	1902-1903.		1903-1904.		Average 21 years.	
	Rain.	Days.	Rain.	Days.	Rain.	Days.
September ..	9·00	17	11·36	27	6·86	16
October ..	25·15	28	13·73	24	14·00	20
November ..	17·43	22	2·71	13	10·86	17
December ..	7·46	18	10·20	19	8·44	13·5
January ..	2·69	8	11·20	19	3·32	7
February ..	1·86	8	1·87	4	1·59	4
March ..	·14	2	3·55	7	4·52	8
April ..	6·88	11	3·54	9	9·59	14
May ..	12·33	17	9·90	17	6·95	12
June ..	5·74	17	18·98	30	10·43	20
July ..	7·36	27	11·71	29	7·87	19
August ..	3·13	17	3·70	12	5·75	17

The above table may be left to tell its own story. As regards temperature, the mean is very uniform all the year round, ranging from about 74° F. in January to 78° F. in May. The difference between the maximum and minimum temperature is greater in dry weather than in wet. Thus the greatest daily range of temperature occurs in January or February, at the beginning of the relatively dry season terminating the north-east monsoon, when the difference between day and night temperatures may be as much as 25° F. The smallest range is recorded during the wet weather of the south-west monsoon in June and July, when the *average* difference between maximum and minimum is about 10° F.

I shall proceed to give a short account of the changes in the weather and general conditions to which each generation grown was exposed.

(1*a*) The first batch of seeds was sown on September 19th, 1902. The earlier half of the month had been wet, but no rain fell between September 21st and 30th ; and the hot sun caused some damage to the seedlings just as they were appearing above the ground. Abundant rain set in at the beginning of October, and the weather continued to be very wet during the remainder of the life of the plants—a total period of a little more than three months. The plants, however, failed to recover and were all very weakly. This result was partly due to insufficient manuring, for the soil proved much poorer than I had been led to anticipate.

A number of pollinations was performed upon the flowers of these plants, but only a small proportion of them was successful, and the pods which developed gave rise to a very small number of seeds. The seeds ripened in somewhat drier weather at the end of December, but there was very little crop to gather.

(1*b*) A further series was sown on October 20th ; and afterwards serial sowings of a few varieties were continued up to the middle of December. Heavy rain did some damage to the earlier series during October and November ; and a strong north-east wind cut off the tops of the later plants in January and February. A batch sown towards the end of November did best, and upon these a few more crosses were made with better success, the seeds being gathered in dry weather during February and March.

(2) Seeds obtained as a result of some of the crosses between the plants of series (1*a*) were sown between December 12th and 19th, (1902). Nearly all the seeds that were sown germinated and the plants did well at first, appearing to derive some benefit from the cooler nights of January. Later on they suffered greatly from wind and drought, and many were killed in this way ; those which survived gave only a poor crop.

Trial plants from seeds sown in January and constantly watered produced quite remarkably stunted plants, which began to flower at half the usual height* and produced almost no seed.

Plants from seeds sown in February or March rarely reached the flowering stage at all, owing to the excess of sun and lack of moisture.

(3) Offspring of crosses, both F_1 and F_2, were next sown on the 2nd and 5th of May. Twelve inches of rain fell between the 2nd and 21st of May, and this was followed by a drought until June 4th. At the beginning of June the plants were found to have been attacked by a mildew which subsequently became very serious. Practically all the seeds that were sown germinated and very few of the plants died; as a consequence the plants grew too close together (allowance having been made for a certain number of casualties) and the fungus was thus enabled to spread rapidly. The plants were also damaged by an alternation of showers and bright sunshine, which occurred frequently in June and caused a blistering of the young leaves and stipules.† The seeds were gathered at the beginning of August and the crop was a particularly poor one.

(3*a*) A series of the original strains which was sown early in April grew moderately well, and some further crosses were made upon them.

(4) The seeds from these last were sown immediately they were ripe, that is to say on the 9th of July. These fared even worse than the previous series, meeting with dry weather in August, when rain was much needed, and ripening in very wet weather at the beginning of October. They were somewhat mildewed and yielded hardly any seeds or useful result, and none of their progeny were reared.

(5) The next series—F_2 and F_3, the offspring of (3)—were sown on October 26th, 1903. A very large number failed to germinate (*i.e.*, about 80 per cent. of those sown, a state of things which is doubtless to be explained by the bad conditions to which the plants

* *I.e.*, of plants sown in November.

† Showing very clearly by contrast the protection afforded the older foliage by its thick epidermal covering of wax.

which bore these seeds were exposed) ; those which survived developed into the best plants which I had yet seen, the conditions of growth being good almost throughout ; in spite of a dry November, during which however the rain that fell was well distributed. During the last week of January, just when the seeds of this crop were ripening, there fell more than 8 inches of rain. The early part of February however was rainless, and I was able to get many of the seeds dry.

By this time the process of selecting the strongest offspring of certain crosses appeared to have had a considerable effect in the direction of producing vigorous plants. For the third and fourth generations of the original uncrossed strains, grown at the same time as the above and from seeds taken in each generation from the strongest surviving plants showed practically no advance upon the original generation, as grown at first from English seed, and were very poor in comparison with the cross-breds, and this effect was still more clearly seen in a further generation.

(6) This arose from seeds sown on April 6th, 1904, and underwent a drought lasting from the 14th to the 27th of the month, during which time the young plants were with difficulty kept alive by constant watering and shading. Even then very little rain fell until the south-west monsoon " broke " with considerable violence on May 20th. After this constant heavy rain continued to fall during the whole of June and July and the plants ripened their seeds in very wet weather. Thus the conditions during the whole of the life of these plants appeared to be distinctly unfavourable. Practically every seed sown germinated, a fact which evidently depends upon the favourable conditions enjoyed by the previous generation ; and although a good many seedlings perished—especially the offspring of certain combinations—enough were left to make a very good show at the time of flowering. The wet weather which prevailed at the time of ripening caused much damage ; nevertheless the crop was by far the best obtained throughout the whole series of experiments, and would doubtless have been most valuable as a source of profitable varieties if it had been possible to dry the seeds.

It is unfortunately true that in the case of all these experiments no two generations were strictly comparable one with another as regards the external conditions under which they were grown. Moreover external conditions have unmistakably a large influence upon the growth of the plants, an influence which, as De Vries has pointed out, probably extends over more than one generation. It is nevertheless clear that a marked improvement in the vigour and prolific habit of the plants was arrived at by the process of crossing and then selecting the strongest plants from among the progeny of the cross-breds. Natural selection also played a part in determining the later generations, as may be gathered from the above account. Simple selection of uncrossed strains, in conjunction with rigorous natural selection, did not lead to any advance of a comparable kind.

The effect of the climate of Peradeniya upon pure strains of English peas next demands attention. The exact result seemed to vary in different cases. Thus, when sown in November, French Sugar Pea grew to a considerably greater height than was to be expected from the description accompanying the sample. On the other hand Earliest Blue Pea was much more dwarf. The particular effect in different cases will be described later on, but in this place I would emphasize the fact that the whole result appeared at once in the plants grown at Peradeniya from English seed, and that subsequent generations grown from the seed which these produced closely resembled this first generation. The following races retained for five generations the characters distinctive of the first generation as grown at Peradeniya :—Telegraph, Telephone, Ringleader, French Sugar, Fillbasket, Satisfaction, and Sutton's Earliest Blue Pea. The last-named, which was also the most modified, may be more particularly described by way of example.

The first generation (English seed) was sown on November 29th, 1902. 426 seeds were sown in a bed manured as evenly as possible. The seeds were planted in two rows 4 inches apart and 2 inches apart in the rows. The seeds were ripe on January 20th (seven weeks and three days after sowing), and 398 plants were then gathered in. The height of these plants varied from 6 to 22 inches, the mean height being about 14 inches. The great majority of plants produced only one pod each, five plants bore two pods each, and sixteen plants had no pods at all. The total number of seeds was 776, or on the average a little over two per pod. The seeds were less rounded and more irregular in form than the original sample—doubtless an effect of nutrition.

400 of these seeds were sown on January 27th, for the second generation, and 388 plants were gathered in on March 17th. The mean height of the plants was about 15 inches, and the heights were rather more uniform. The plants bore 595 seeds in 397 pods.

400 of these seeds were sown on June 4th, and 327 plants were gathered in on July 26th. These plants produced 1,065 seeds in 444 pods. The average height was only very slightly greater than in the previous generation and the seeds were similar in form and size. Now Earliest Blue Pea as grown in England is described as being on the average 3 feet in height, and the crop must be of course on quite a different scale from that which is here described—consisting of only two or three seeds per plant.

The effect of climate shown in this case was exceptional in degree, but the immediate result and the preservation of the type of the first generation are points typical of all the kinds of peas examined.

METHOD.

In making the following crosses, the stamens were in all cases removed from the flower to be pollinated previous to the opening of the anthers, and no case of erroneous self-pollination was recorded. The flowers after they had been pollinated were covered with bags of parchment paper, chiefly for the purpose of protecting the buds thus prematurely opened, from the effects of rain and sunshine.

In the succeeding generations the plants were in all cases left to themselves, no attempt being made to cover the flowers. In no case, whether of a pure strain or of a cross-bred plant, was there any indication that anything but self-fertilization had taken place.

EXPERIMENTS IN CROSSING.

1.—Telegraph crossed with Native Pea No. 1.

A.—*Description of Parents.*

Sutton's Telegraph pea.—This is described as being on the average 5 feet in height, and as being "Singularly free from the frequent objectionable sports."

The sample obtained consisted of large seeds which varied a good deal in shape, and as regards surface might usually have been described as almost dimpled. The starch grains however are of the form typical for "round" peas, and the seeds therefore belong to the "round" group as distinguished from the "wrinkled."* The cotyledons were of a deep green colour with hardly any tinge of yellow in the great majority of cases. The testas were white and semi-transparent. The seeds varied in longest diameter from 7 to 10 mm., the average of 500 being 8·7 mm.

As grown in Ceylon the average height of the plants was about 5 feet; but the height was also very variable, ranging from 3 to 7 feet in different individuals. The stems were stout and the foliage large. The flowers were always pure white. The pods were large—about 20 mm. in width—and well inflated, and they tapered to a point at the apex. The seeds were not so well "filled out" as those of the original sample, but were elongated and nearly square in cross section.

447 seeds, gathered in February, 1903, from plants of the first generation, included 68 per cent. fully green seeds, 30 per cent. piebald or tinged with yellow, and 2 per cent. fully yellow.

Selection of the roundest and of the most wrinkled seeds of the original sample had practically no effect upon the form of the offspring, which was slightly more irregular than in the first generation.

Native pea No. 1.—The plants of this form are slim and the foliage small. The height varied enormously according to the time of sowing and the amount of moisture. In this way the *average* height varied from 3 feet to 5 feet 6 inches; but the variation among the individual plants was less than in the case of Telegraph. The

* Cp. p. 324.

pods were small and narrow (about 13 mm. in width) and were truncated at the apical end. They were always fully inflated. The flowers were white.

The seeds were from 4·5 to 8 mm. in greatest diameter; and 6·5 mm. was the average length of 2,000 of them. They were nearly spherical and usually quite smooth (starch grains of the round type); the cotyledons were always of a bright and uniform orange-yellow colour. The testas were white and semi-transparent, but sometimes slightly tinged with green in the case of seeds which had dried off rapidly in the upper pods of a plant.

B.—*The Cross-bred Plants.*

1.—*Native pea No.* 1 × *Telegraph.**—In all 20 crosses were attempted, of which 12 were successful and gave rise to 31 seeds. All closely resembled the seeds of No. 1 in every visible respect. Four of these crosses, which were made in January, 1903, resulted in the production of 5 seeds per pod (the normal average number for the maternal kind), but the others, which were made in November, 1902, gave relatively a very poor result.

The latter seeds were sown in December, 1902. The plants which arose from them were about 5 feet in height and in their somewhat large foliage and stout habit approached the type of Telegraph. The pods were intermediate in general form, but with a truncated apex, and were from 15 to 18 mm. in width.

2.—*Telegraph* × *Native pea No.* 1.—As the result of 30 pollinations 17 pods were obtained containing altogether 50 seeds. In shape these closely resembled the normal seeds of Telegraph, but the colour of the cotyledons was in all cases bright yellow. The plants arising from these seeds, sown at the same time as those of the reciprocal cross, closely resembled the latter. Other seeds sown on May 2nd produced much taller plants. Some of the characters of the latter are indicated in the accompanying table, together with the cotyledon characters of their seeds, which belong of course to the next generation—F_2. In size and shape, which appear to be maternal

* Here and subsequently the seed-parent is placed first and the pollen parent second. × is thus to be read "fertilized with pollen from."

characters, the seeds of the same plant were all nearly alike—the size intermediate, the shape nearly that of Telegraph.

Table I.

Date of Sowing.	Number.*	Height (Inches).	Number of Nodes.	Average Length of an Internode (Inches).	Number of Branches.	Number of Pods.	Width of an Average Pod (mm.).	Number of Seeds.	F^2.		
									Yellow.	Green.	Bad.
19-12-02	181.1	58	28	2·1	—	10	—	23	10	5	8
	180.1	58	28	2·1	—	5	—	15	14	1	—
	304.1	59	29	2·1	—	5	—	15	7	8	—
	.2	46	25	1·8	—	2	—	7	4	3	—
2-5-03	371.1	88	31	1·8	2	4	16	7	5	2	—
	.2	84	27	3·1	—	6	17	17	11	6	—
	.3	89	29	3·1	—	6	15	11	10	1	—
	.4	91	32	2·8	2	15	17	27	20	7	—
	.5	95	32	3·0	1	7	17	19	14	5	—
	372·1	88	35	2·5	2	10	16	21	15	6	—
	.2	85	34	2·5	2	1	16	3	2	1	—
	.3	99	35	2·8	—	10	18	32	24	8	—
	435.1	87	26	3·3	—	6	16	14	11	3	—
	.2	90	29	3·1	1	8	17	23	20	3	—
	.3	95	31	3·1	1	10	16	26	21	5	—
	.4	100	32	3·1	1	5	19	18	13	5	—
	.5	80	27	3·0	1	8	17	22	17	5	—
	436.1	76	24	3·2	—	6	15	14	10	4	—
	.2	86	32	2·7	—	5	.17	14	10	4	—
	.3	98	33	3·0	—	5	18	9	6	3	—
	459.1	80	31	2·6	—	2	15	3	2	1	—
	.2	85	31	2·7	—	3	16	6	6	—	—

* The numbers which are prefixed to the different hybrids and their progeny require a word of explanation. The crosses of all kinds made at Peradeniya were numbered consequtively; the plants arising from each seed of a cross-bred pod then received a distinguishing number, when these were more than one; and in the next generation a further number was added to distinguish the different offspring of each of these plants. Thus 371.1, 2, 3, &c., are plants arising from different seeds of the same cross-bred pod.

The greater length of the internodes of the plants which developed from seeds sown on May 2nd is partly due to the fact that the plants were grown much too close together, and partly to the different season with more moisture and less sunshine. The plants were all badly mildewed. Half the plants grown at this time produced one or more branches.

C.—*Further Generations.*

1.—*Native pea No.* 1 × *Telegraph,* F_2, *and* F_3.—Six plants from F_1 seeds sown on December 8, 1902, produced the following seeds :—

No.		Yellow.		Green.
157.1	..	11	..	5
186.1	..	11	..	5
.2	..	10	..	4
238.1	..	10	..	5
.2	..	8	..	7
303.1	..	18	..	13
Total	..	68		39 or 1·74: 1.

In only two cases could any trace of yellow be detected in a "green" seed, as examined through the semi-transparent testa—a proportion of 5 per cent., which may be compared with the 30 per cent. found in the uncrossed strain of Telegraph.

Of the 107 seeds, 66 were sown on May 2nd, 1903, but only the plants arising from 21 yellow and 11 green seeds produced fruits. They ranged from 45 to 102 inches in height, the average being nearly 7 feet.

Table II.

	F_2.					F_3.		F_2.	
Number.	Height (Inches).	Number of Nodes.	Width of a Pod (mm.).	Number of Pods.	Number of Seeds.	Yellow.	Green.	Colour of Seed sown.	Nature of Seed sown.
180.1.1	64	20	12	2	5	4	1	y	DR
.2	83	27	16	3	6	4	2	y	DR
.3	88	28	17	5	16	—	16	g	R
.4	90	32	15	5	13	—	13	g	R
.5	85	30	18	1	5	—	5	g	R
.6	77	27	17	1	3	—	3	g	R

D. The yellow seed was a pure dominant.

R. The green seed was pure recessive.

DR. The yellow seed was a heterozygote.

	F_2.					F_3.		F_2.	
Number.	Height (Inches).	Number of Nodes.	Width of a Pod (mm.).	Number of Pods.	Number of Seeds.	Yellow.	Green.	Colour of Seed sown.	Nature of Seed sown.
186.2.1	?	?	18	9	28	28	—	y	D
.2	75	27	15	7	27	22	5	y	DR
.3	102	40	16	3	8	7	1	y	DR
.4	87	30	18	3	6	5	1	y	DR
.5	84	26	16	7	14	14	—	y	D
.6	?	?	14	4	13	13	—	y	D
.7	87	32	19	2	7	—	7	g	R
.8	61	20	17	2	4	—	4	g	R
238.1.1	80	35	16	2	9	7	2	y	DR
.2	65	28	14	4	15	13	2	y	DR
.3	45	32	18	6	12	11	1	y	DR
.4	?	?	14	4	12	8	4	y	DR
.5	90	33	16	2	8	6	2	y	DR
.6	88	29	17	3	11	—	11	g	R
.7	80	29	15	2	3	—	3	g	R
.8	71	25	18	5	10	—	10	g	R
303.1.1	75	25	15	2	4	3	1	y	DR
.2	80	26	16	2	4	4	—	y	D ?
.3	65	25	13	4	12	7	5	y	DR
.4	80	30	16	3	7	5	2	y	DR
.5	80	29	13	3	13	11	2	y	DR
.6	73	25	16	3	8	8	—	y	D
.7	64	23	14	2	4	4	—	y	D ?
.8	61	22	14	5	7	6	1	y	DR
.9	77	26	18	4	10	—	10	g	R
.10	72	22	17	2	6	—	6	g	R

The width of an average pod from each of the different plants showed the following range :—

Width	19mm.	18	17	16	15	14	13	12
Number of plants	1	6	5	8	4	5	2	1

We may regard this as indicating the proportion 7 wide : 17medium : 8 narrow, or nearly 1 : 2 : 1. The Mendelian ratio thus makes its appearance in spite of much variability.

The 11 plants which arose from green seeds (F_2) gave rise to exclusively green seeds (F_3), namely to 88 such seeds.

Of the 21 plants arising from yellow seeds (F_2), 6 produced only yellow seeds (F_3), namely, 71 seeds all bright orange-yellow in colour. The remaining 15 plants gave rise to both yellow and green seeds—altogether 118 yellow and 32 green, or 3·7 to 1. In the most doubtful cases (perhaps half a dozen in all) in which the colour could only be seen indistinctly through the testa, on removal of the latter the cotyledons were found to be either bright yellow or bright green. It is therefore safe to assert that practically all the seeds were either fully yellow or fully green; certainly the "green" seeds did not include so high a proportion of examples mottled with yellow as in the case of Telegraph. And it thus appears as if the act of crossing had rendered the green pigment more stable in the extracted homozygotes.

The following scheme indicates the course of this experiment:—

No. 1 x Telegraph

F_1. 31y
6

F_2. 68y — 39
21 — (36·5 per cent.)
6 (28 per cent.) — 15 — 11

F_3. 71y — 118y — 32g (21 per cent.) — 88g

2.—*Telegraph* × *Native pea No.* 1, F_2, F_3, *and* F_4.—The cotyledon colour of the seeds (F_2) on F_1 plants gathered in February and at the end of July, 1903, were detailed in Table I., the total being 302 yellow, 86 green. The following table embraces the same detail for a further series gathered on October 10th, 1903, in very wet weather:—

No.	Y.	G.	No.	Y.	G.	No.	Y.	G.
618.1	8	5	.3	8	6	636.1	16	10
.2	11	4	.4	6	2	.2	11	4
.3	17	4	626.1	14	3	.3	22	6
.4	9	4	.2	10	7	637.1	11	2
.5	16	1	.3	10	3	.2	4	2
.6	11	3	.4	9	4			
619.1	16	2	627.1	13	4	Total ..	263	87 or 3 : 0.99.
620.1	8	1	627.2	10	5			
620.2	9	3	.3	14	2			

Out of a total of 87 green seeds 2 were noticed to show distinct patches of yellow and others were of a somewhat dull shade of green. All however were readily distinguishable from the "yellows" in spite of the unfavourable conditions during ripening.

The total figures for this and later generations were summed up in a previous paper on page 309. Details for F_2 are given in the following table :—

F_2.					F_3.			F_2.	
Number.	Height (Inches).	Nodes.	Branches.	Pods.	Seeds.	Yellow.	Green.	Colour of Seed Sown.	Nature of Plants.
618.1	84	31	—	7	36	25	11	y	DR
(1–6) .2	84	30	—	11	38	31	7	y	DR
.3	71	25	—	7	23	17	6	y	DR
.4	90	34	1	15	59	46	13	y	DR
.5	62	24	—	5	14	11	3	y	DR
.6	81	26	—	6	23	23	—	y	D
.7	86	29	—	9	31	24	7	y	DR
.8	80	33	2	10	50	41	9	y	DR
.9	70	28	2	12	45	45	—	y	D
.10	82	32	2	14	42	35	7	y	DR
.11	86	31	—	12	45	45	—	y	D
.12	85	29	—	9	22	12	10	y	DR
.13	75	29	—	7	33	33	—	y	D
.14	73	28	—	5	22	15	7	y	DR
.15	82	33	1	10	39	39	—	y	D
.16	98	40	1	11	56	43	13	y	DR
.17	101	35	—	13	54	54	—	y	D
.18	85	31	1	8	39	39	—	y	D
.19	94	37	—	9	40	32	8	y	DR
.20	64	29	—	6	19	18	1	y	DR
.21	72	29	—	7	34	—	34	g	R
.22	61	28	—	5	22	—	22	g	R
.23	84	34	—	17	63	—	63	g	R
.24	52	22	—	5	16	—	16	g	R
.25	43	20	—	2	6	—	6	g	R
.26	50	24	—	5	15	—	15	g	R
.27	60	—	—	9	33	—	33	g	R
.28	70	27	—	8	27	2	25	g	R

F₂.					F₃.			F₂.	
Number.	Height (Inches).	Nodes.	Branches.	Pods.	Seeds.	Yellow.	Green.	Colour of Seed Sown.	Nature of Plants.
.29	74	28	—	10	16	—	16	g	R
.30	79	32	—	8	28	2	26	g	R
.31	78	34	—	—	18	18	—	y	D
435.1.1	84	36	2	19	62	62	—	y	D
.2	84	33	2	14	50	37	13	y	DR
.3	92	35	3	21	74	53	21	y	DR
.4	94	28	—	11	32	29	3	y	DR
.5	87	33	1	14	48	39	9	y	DR
.6	90	33	—	12	39	27	12	y	DR
435.2.1	65	—	—	5	20	17	3	y	DR
.2	63	25	—	4	14	11	3	y	DR
.3	75	27	1	15	49	42	7	y	DR
.4	90	32	2	24	76	76	—	y	D
.5	71	29	—	4	15	8	7	y	DR
.6	64	27	—	5	13	10	3	y	DR
.7	70	32	—	11	38	29	9	y	DR
435.3.1	95	39	6	51	209	209	—	y	D
.2	90	31	2	18	74	55	19	y	DR
435.4.1	77	32	1	9	48	48	—	y	D
.2	92	28	—	12	41	26	15	y	DR
.3	96	39	5	46	155	118	37	y	DR
.4	90	32	3	20	82	82	—	y	D
435.5.1	80	26	1	16	64	64	—	y	D
.2	79	31	—	12	38	26	12	y	DR
.3	92	33	1	14	68	68	—	y	D
.4	—	37	4	28	108	108	—	y	D
.5	68	28	2	13	35	—	35	g	R

Thus, out of 44 yellow seeds sown, 16 plants gave rise to 1,013 yellow seeds only, whilst 28 plants yielded a mixture—altogether 877 yellow and 275 green seeds, or 3 : 0·94. Eleven plants from green seeds produced 291 green seeds and 4 yellow, the latter being probably examples of the effect of exposure upon properly green seeds, such as was described as being frequent in the case of Telegraph seeds.

Out of 55 F_2 plants 17 were reckoned to bear seeds of the spherical or No. 1 type in narrower pods, whilst 36 bore seeds of the Telegraph type in wider pods. Actual measurements were not made and the distinction was not very clear.

In F_3, 134 plants were raised, offspring of 7 plants which proved the most prolific in F_2. Of the 7, 2 included only plants with moderately narrow pods (but wider and more variable than those of No. 1); and these bore seeds which were all nearly spherical, but variable in size from plant to plant, being on the average larger than those of No. 1. These two families were the offspring of plants which had been reckoned as bearing seeds of the No. 1 type in F_2.

Of the other five families—offspring of seeds of more or less the Telegraph type—two consisted wholly of plants with pods and seeds of the Telegraph type whilst the other three included both types. In two of these cases the proportion of the two types (Telegraph : No. 1) could be distinguished as 13 : 4 and 10 : 2; in the third case there was more variability.

There thus appears to be Mendelian segregation to a certain extent in respect of the characters wide or narrow pod correlated with certain shapes of seeds. But the extracted "recessives" seem still to show signs of the influence of the more or less dominant form (wider pods). So that there is perhaps more complication than in a simple Mendelian case. One source of complication is patent in the fact that the size of seeds appears to be a character independent of their shape. Possibly there is also in some cases a mutual influence between size of seeds and width of pods.

On the other hand, colour of the cotyledons, which was the character to which attention was chiefly directed in the present experiment, was found to gain in distinctness as the result of the cross and to obey Mendel's law with the utmost precision. The green and yellow seeds obtained from heterozygotes in F_2 and F_3 showed, when looked at in bulk, a most marked uniformity among themselves and distinctness from the other type. When kept for some weeks the colour of the green seeds especially became duller, and a tinge of yellow began to appear in some of them.

A summary of the plants raised in F_3 follows, together with the total number of seeds which they produced of either colour :—

Number.	Seeds Sown.	Nature of Plants: F_3 D.	DR.	R.	Seeds F_4 Y.	G.	Bad.
435.1.2	12y	1	.	.	22	—	—
,,	—	.	10	.	244	96	62
,,	6g	.	.	6	—	171	2
435.1.3	24y	4	.	.	185	—	30
,,	—	.	17	.	346	138	13
,,	12g	.	.	11	—	307	8
435.3.2	12y	.	10	.	199	75	21
,,	6g	.	.	3	—	71	5
435.4.1	12y	9	.	.	224	(7)†	12
435.4.2	12y	3	.	.	91	—	—
,,	—	.	7	.	121	39	—
,,	6g	.	.	4	—	126	2
435.4.3	20y	4	.	.	127	—	—
,,	—	.	11	.	25	79	—
,,	20g	.	.	17	—	469	11
435.5.1	12y	4	.	.	117	—	4
,,	—	.	7	.	170	51	9
,,	6g	.	.	6	—	181	—

The above table repeats in rather greater detail the information given previously in Part I., page 309.

Twenty-five green and 25 yellow seeds were taken at random from a large fresh sample of F_4—offspring of heterozygotes—and were examined closely after removal of the testa. The green seeds were without exception of a deeper and more vivid green than the greenest of the 3 peas in Weldon's Fig. 1,‡ being indeed quite green. The yellow seeds were all as yellow as those in Fig. 6, but of a darker shade —almost exactly the shade of the yellow ink used for printing the figure. It is to be noticed that all these seeds were produced upon plants of much more vigorous and healthy appearance than those of F_1, a fact which suggests that the relatively " bad " results obtained in the earlier generations may have been due to the bad conditions of growth, or want of acclimatization.

* Nearly all the seeds set down in this column had been attacked by a caterpillar, causing damage which rendered the discrimination of their colour a matter of uncertainty.

† Not fully ripe.

‡ Biometrica, I., 1902, Pt. II.

2.—Telegraph crossed with Ringleader.

A.—*The Parental Types.*

1. For *Telegraph* see above. 2.—*Ringleader.*—Cotyledons perfectly yellow and smooth; seeds a little flattened from side to side. Plants on the average less than 3 feet high ; pods containing very few seeds but comparatively numerous upon the plants. Flower stalks very long ; pods truncated at the ends.

B.—*The Cross-bred Forms.*

1. *Telegraph* × *Ringleader.*—Twelve seeds were obtained from 3 successful crosses ; all of them were fully yellow and resembled in shape the smoother examples of the normal Telegraph type. All these seeds gave rise to fruitful plants, which were of nearly the same height as Telegraph and closely resembled that parent except in the greater length of the flower stalks and the truncated ends of the pods.

2. *Ringleader* × *Telegraph.*—Eleven seeds resulted from 4 crosses, these were not to be distinguished from uncrossed seeds of Ringleader. The 11 plants resembled those arising from the reciprocal cross.

C.—*Further Generations.*

1. *Telegraph* × *Ringleader*, F_2.—The following seeds were readily distinguished according to colour; in shape they closely resembled those of Telegraph :—

No.	Yellow.	Green.	
427.1	18	5	
.2	12	4	
.3	11	3	
.4	5	5	
.5	14	5	
.6	13	7	
444.1	15	2	
.2	14	4	
.3	20	7	
.4	11	5	
445.1	8	4	
.2	11	5	
.3	10	2	
Total .. —	162	58	or 3 : 1·07

Out of 50 of these seeds which were sown (on 26th October, 1903) only 6 survived to bear fruit. These were stout plants bearing on the average 13 pods and 42 seeds each :—

Number.	Height.	Number of Nodes.	Branches.	Pods.	Seeds.	F_3. Yellow.	Green.	F_2. Colour of Seed Sown.	Nature of Seed Sown.
427.1	80	31	1	18	56	43	13	y	DR
.2	78	31	—	10	33	24	9	y	DR
.3	75	31	1	14	38	38	—	y	D
444.1	71	?	3	19	59	59	—	y	D
.2	76	26	—	10	41	41	—	y	D
.3	59	26	—	9	28	24	4	y	DR

2. *Ringleader* × *Telegraph*, F_2.—The following yellow and green seeds were readily distinguishable :—

No.	Yellow.	Green,
424.1	10	3
.2	15	3
.3	9	4
.4	6	1
425.1	10	5
.2	12	5
.3	12	3
446.1	12	4
.2	8	4
449.1	6	5
.2	13	7
Total	113	44 or 3 : 1·17

The total numbers for the two reciprocal crosses in F_2 are as follows :—Yellow 274 : green 102, or 3 : 1·1.

3.—Telephone crossed with Native Pea No. 1.

A.—*The Parental Types.*

1. *Telephone.*—(Sample obtained from Messrs. Sutton.) "Average height 5 feet." In my experience Telephone is a typically wrinkled pea. As regards colour the cotyledons show a high degree of susceptibility to the effect of light, the result of which is gradually

to change the green colour to yellow. This change does not take place uniformly, and so a piebald effect is often produced. The original sample of seeds was almost entirely green. It was kept in a stoppered glass bottle exposed to the light of an ordinary room, and by the end of six months the cotyledons on the exposed side had all become completely yellow. Other kinds of peas with green cotyledons showed a similar change, but this took place more slowly than in the case of Telephone.

A majority of the first crop seeds at Peradeniya were more or less yellow when gathered, distinctly more so even than in the case of Telegraph. They were separated into three groups—green, piebald, and yellow, respectively—the groups being as it happened nearly of equal size, and 50 seeds of each kind were sown. The crop from each group was again separated into a like threegr oups, but the offspring of yellow seeds did not include a larger proportion of yellows than the others. The exact numbers of these samples are of no value, owing to the want of definite limits to the different groups, but it was clear that the tendency to turn yellow was inherited nearly equally by the offspring of all three groups. In the above cases the seeds were left on the plants for some days after all were ripe; cross-bred plants, on the other hand, were always taken up before the seeds in the topmost pods were quite hard, and the seeds examined at once; under such circumstances the green colour could almost always be detected in the parental strain also.

B.—*The Cross-bred Forms.*

1. *Native pea No. 1* × *Telephone.*—Twenty-one cross fertilizations were made, of which only 9 were successful. The 9 pods yielded 20 seeds, none of which differed at all from the normal seeds of No. 1.

The crosses were made in November, 1902, and the seeds were sown immediately after gathering; all but two germinated, but only 14 plants produced seeds. The plants reached a height of 3–4 feet, nearly the same as that of the best plants of the two parental forms sown at the same time. In the character of their foliage and in stoutness of stem they resembled Telephone, but there appeared to be a slight reduction in these features traceable to the other parent. The pods were nearly as wide as those of Telephone, but were shaped like those of No. 1 (dominance of the blunt apex). The size of the seeds was intermediate; the shape (apart from the question of smoothness or wrinkling) much nearer to that of Telephone.

2. *Telephone* × *Native pea* No. 1.—Eighteen pollinations were attempted, 12 successfully, with 27 seeds as the result. With the exception of 2 seeds contained in a single pod, all these seeds were fully yellow as regards cotyledon colour. All the seeds were nearly smooth in surface; some of them showed a very slight dimpling; but all were smoother than any which I could find among the same generation of pure bred Telephone seed. In general form and size, on the other hand, they closely resembled the smoothest seeds of Telephone, which are also closely similar to those of Telegraph, differing entirely in these respects from No. 1.

One cross out of the 12 gave rise to 2 fully green seeds, resembling in shape the other examples of the same cross. Occurring as they did on a green seeded plant the suspicion arises that these seeds may have been the result of accidental self fertilization. But I do not believe that this can have been the case; firstly because the seeds were smooth, and secondly because their offspring behaved, so far as the evidence went, like those of a cross between smooth and wrinkled. The individual plant from which the pollen was taken was not specially examined, but all the seeds were gathered from the whole row of plants used for this purpose, and none of the cotyledons showed any trace of greenness.

Of the above-mentioned crosses, 6 which were made in November, 1902, resulted in 10 seeds, from only 4 of which fertile offspring were obtained. In both cases the seeds were sown shortly after they were gathered, and the plants closely resembled those from the reciprocal cross.

C.—*The Offspring of Cross-bred Plant*—F_2.

1. *Native pea No. 1* × *Telephone*.—The seeds produced by the cross-bred plants exhibited four distinct combinations of cotyledon characters, being in almost all cases readily distinguishable as

smooth yellow, smooth green, wrinkled yellow, or wrinkled green, respectively. The green seeds appeared to show less susceptibility to the effects of exposure than those of the pure Telephone stock, and only a few, and these obviously badly developed, showed any yellow patches. Although this is partly accounted for by the fact that they were gathered sooner, this does not appear to be the whole explanation, but it seems clear that there was an actual intensification as the result of the cross. It was also noticed, on examining the seeds after the removal of their coats, that the shade of colour, whether yellow or green, was distinctly paler in the wrinkled cotyledons than in the smooth ones.*

Even without removing the coats it was hardly ever possible to confuse yellow seeds with green ones, but the discrimination between smooth and wrinkled seeds was more difficult, owing to the fact that seeds properly belonging to the smooth group were often a good deal pitted and irregular in shape. The result of the actual sampling was as follows :—

No.	sm. y.	sm. g.	wr. y.	wr. g.
159.1	9	2	4	—
202.1	4	4	—	—
209.1	15	6	2	2
.2	9	3	1	2
.3	—	2	1	—
210.1	12	5	1	1
212.1	10	3	2	2
.2	5	2	—	2
267.1	8	7	3	2
269.1	12	4	3	2
2	10	—	2	—
.3	1	—	1	—
270.1	10	3	3	—
.2	5	3	5	1
Total	110	44	28	14
Expectation	110	36.7	36.7	12.2

* *Cf.* Hurst, J. R. H. S., 1903.

It is perhaps noteworthy that a total so nearly approaching the expected should be derived from such small individual figures.

144 of these seeds were sown on 3rd May, 1903, only those from the weakest of the above plants being excluded. 98 plants yielded fruit, but the majority gave only a poor crop. Most were very tall, but this effect was partly due to overcrowding. In general appearance all were much alike—the pale green foliage of Telephone being still visible—and the stipules were broad. The plants were badly mildewed and damaged by alternate rain and sunshine.

The width of the pods appeared to be tolerably constant on each plant, but between different plants the variation was considerable. The width of a typical pod was measured in the case of each of 78 plants—all that had pods typically developed—with the following result :—

Width	..	19 mm.	18	17	16	15	14	13
Plants	..	2	.. 9	.. 22	.. 17	.. 9	.. 14	.. 5

If we draw an arbitrary line between the widths of 14 and 15 mm., as we are to some extent justified in doing, because (1) the width of the pods of No. 1 was from 13–14 mm., and (2) the figures show something of a natural demarcation at that point, we find the ratio of wide, intermediate, and narrow to be 59 : 19 or 3.1 : 1.

2. *Telephone* × *Native pea No.* 1.—The cotyledons fell into the same four groups as the above. In three cases it was necessary to remove the seed coat before the colour of the cotyledons could be ascertained with certainty : all three proved to be fully yellow, and this had been partly obscured by a greenish tinge in the testa. In these and in all other cases the two classes of colour were quite distinct, although some of the green seeds showed slight yellow patches. Smooth and wrinkled seeds were more difficult to distinguish by the eye, the former being all more or less pitted. The majority of the wrinkleds were thoroughly so.

The seeds were sorted as follows:—

No.	sm. y.	sm. g.	wr. y.	wr. g.
245.1	4	3	4	1
246.1	7	2	1	—
295.1	2	1	1	—
610.1	2	1	1	1
621.1	4	4	4	2
.2	8	3	1	1
.3	4	3	2	1
622.1	14	4	1	1
.2	3	1	3	1
.3	8	3	1	1
623.1	9	5	2	1
.2	3	1	1	—
.3	2	1	2	1
.4	10	4	4	—
.5	10	1	4	1
631.1	2	1	1	—
.2	6	1	1	1
634.1	7	5	5	1
.2	6	2	1	—
Total	111	46	40	14
Expectation	118·8	39·6	39·6	13·2

An even smoother result than in the previous case, in spite of the very small individual samples.

Exceptional case.—No. 215, which produced 2 green seeds in F_1: one of these gave rise to a plant which fruited, yielding 4 pods and 8 green seeds. Five of these were smooth and 1 was wrinkled; 2 were very small and irregular and neither of the latter germinated.

The seeds from Nos. 610–634 were gathered in October, 1903, in very wet weather. Many of them were sown on the 26th of the same month, and germinated very badly. The survivors however grew into strong plants, many of which bore a good crop of seeds. 55 plants were harvested. Of these, 13 had pods distinctly narrow and of the No. 1 form, the seeds being small and spherical, or much wrinkled, or both. The foliage of these plants was small, and they showed a general resemblance to the No. 1 type. The remaining 42 plants showed a nearer approach to the type characteristic of Telephone, as regards the form of both the seeds and the foliage, and had wider pods. 42 : 13 = 3·2 : 1 ; so that it appears likely that there is Mendelian segregation of these characters, but that the form of seeds and of foliage and the width of pod are all to some extent correlated. It is possible that in the case of the reciprocal cross a similar phenomenon may have been overlooked owing to the bad conditions under which the corresponding generation was grown.

D.—*Further Generations.*

These were grown in the first place to test the accuracy of the sampling in F_2, and, this being found accurate, to test the conformity to Mendel's law in these later generations. It was also hoped to obtain improved strains by the selection of the parents yielding the largest crops and the finest seeds.

1. *Native pea No.* 1 × *Telephone.*—The following table shows how far the constitution of the F_2 seeds could be determined on examining their offspring in F_3:—

Number.	Character of F_2 Seeds.	F_3 Seeds born on F_2 Plants.				Constitution of F_2 Plant.*
		sm. y.	sm. g.	wr. y.	wr. y.	
159.1.1	sm. y.	13	—	3	—	AaB
.2	,,	—	4	—	—	?
.3	,,	9	—	8	—	AaB
.4	,,	10	4	3	—	AaBb
.5	sm. g.	—	9	—	—	AB
.6	,,	—	3	—	—	?
.7	wr. y.	—	—	9	3	aBb
.8	,,	—	—	11	7	aBb
.9	,,	—	—	20	—	aB
.10	,,	—	—	13	8	aBb
202.1.1	sm. y.	15	—	—	—	AB
.2	,,	9	1	1	—	AaBb
.3	sm. g.	—	22	—	7	Aab
209.1.1	sm. y.	2	—	3	—	?
.2	,,	7	—	1	—	?
.3	,,	3	—	1	—	?
.4	,,	3	2	3	—	AaBb

* A = Smooth (Dominant), a = wrinkled (Recessive).
B = Yellow (Dominant), b = green (Recessive).

Number.	Character of F_2 Seeds.	F_3 Seeds born on F_2 Plants.				Constitution of F_2 Plant.*
		sm. y.	sm. g.	wr. y.	wr. g.	
.5	,,	8	—	—	—	AB
.6	,,	5	—	—	—	?
.7	,,	2	2	2	—	AaBb
.8	,,	1	2	1	1	AaBb
.9	,,	5	—	2	—	?
.10	,,	8	—	—	—	AB
.11	sm. g.	—	—	—	—	Ab
.12	,,	—	9	—	3	Aab
.13	,,	—	12	—	—	Ab
.14	wr. y.	—	—	2	1	aBb
.15	,,	—	—	11	—	aB
.16	wr. g.	—	—	1?	4	ab?
209.2.1	sm. y.	8	2	2	—	AaBb
.2	,,	11	1	—	—	ABb
.3	,,	18	—	3	—	AaB
.4	sm. g.	—	20	—	5	Aab
.5	,,	—	3	—	—	?
210.1.1	sm. y.	5	2	—	—	?
.2	,,	4	—	1	—	?
.3	,,	7	5	—	—	ABb
.4	,,	1	2	—	—	?
.5	,,	—	—	12	—	aB ! (*b*)
.6	,,	5	1	—	—	?
.7	,,	7	—	4	—	AaB
.8	sm. g.	—	5	—	2	Aab
.9	,,	—	3	—	1	Aab
.10	,,	—	4	—	—	Ab?
.11	,,	—	2	—	2	Aab
.12	wr. g.	—	—	—	6	ab
212.1.1	sm. y.	3	—	—	—	?
.2	,,	2	2	—	1	AaBb
.3	wr. y.	—	—	2	—	?
.4	,,	—	—	2	1	aBb
.5	sm. g.	—	3	1?	1	Aab
.6	wr. g.	—	—	—	3	ab
.7	,,	—	—	3?	—	?
215.1.1	sm. g.	—	6	—	—	Ab?
.2	,,	—	11	—	6	Aab
.3	,,	—	8	—	—	Ab
.4	,,	—	12	—	—	Ab
.5	wr. g.	—	—	—	15	ab

* A = Smooth (Dominant), a = wrinkled (Recessive).
B = Yellow (Dominant), b = green (Recessive).

Number.	Character of F_2 Seeds.	F_3 Seeds born on F_2 Plants.				Constitution of F_2 Plant.*
		sm. y.	sm. g.	wr. y.	wr. g.	
267.1.1	sm. y.	16	5	3	1	AaBb
.2	,,	7	—	—	—	AB
.3	,,	5	1	1	1	AaBb
.4	,,	3	2	—	—	?
.5	,,	10	2	—	—	ABb
.6	,,	14	—	4	—	AaB
.7	,,	5	2	—	—	ABb?
.8	sm. g.	—	6	—	2	Aab
.9	,,	—	12	—	4	Aab
.10	,,	—	10	—	2	Aab
.11	,,	—	4	—	—	Ab?
.12	wr. y.	—	—	13	1	aBb
.13	,,	—	—	5	3	aBb
.14	wr. g.	—	—	—	17	ab
.15	,,	—	27	—	—	Ab!(*c*)
269.1.1	sm. y.	7	3	—	1	AaBb
.2	,,	2	1	1	—	AaBb
.3	,,	5	1	8	—	AaBb
.4	,,	8	3	—	—	ABb
.5	,,	23	—	9	—	AaB
.6	,,	4	7	—	—	ABb
.7	,,	7	4	4	2	AaBb
.8	,,	8	—	1	—	AaB?
.9	,,	—	12	—	4	Aab!(*a*)
.10	sm. g.	—	8	—	—	Ab
.11	wr. y.	—	—	2	1	aBb
.12	,,	—	—	3	2	aBb
.13	,,	—	—	4	—	aB?
.14	wr. g.	—	—	—	8	ab
270.1.1	sm. y.	8	1	2	—	AaBb
.2	,,	7	—	2	—	AaB?
.3	wr. y.	—	—	2	—	?
.4	,,	—	—	6	1	aBb
270.2.1	sm. y.	4	1	4	—	AaBb
.2	sm. g.	—	2	—	2	Aab
.3	,,	—	3	—	4	Aab
.4	,,	—	9	—	—	Ab
.5	wr. y.	—	—	3	3	aBb
.6	,,	—	—	8	1	aBb

* A = Smooth (Dominant), a = wrinkled (Recessive).
B = Yellow (Dominant), b = green (Recessive).

Thus by the examination of their seeds in F_3 the constitution of the 72 F_2 plants for which a summary follows could be determined, as well as that of four of the offspring of the exceptional cross No. 215. Twenty other plants gave too poor a crop to allow of this being done :—

Parent Seed.	Mendelian Constitution of Parents.									Total.
	AaBb.	AaB.	AaB.	ABb.	aBb.	AB.	Ab.	Ab.	ab.	
Sm. y. ..	15	7	(1)	5	—	4	—	(1)	—	33
Sm. g. ..	—	—	12	—	—	—	5	—	—	17
Wr. y. ..	—	—	—	—	12	—	—	3	—	15
Wr. g. ..	—	—	—	—	—	—	(1)	—	6	7
Total ..	15	7	13	5	12	4	7	4	7	72

The figures are not sufficient for testing the distribution according to Mendel's law with any exactness, though so far as they go the agreement is clear enough. They do afford however a test of the accuracy of the sampling.

There are apparently three errors among the 72 cases, namely :—

(*a*) 1 seed sown as sm. y. gave rise to sm. and wr. green only.

(*b*) 1 seed sown as sm. y. gave rise to wrinkled yellow only.

(*c*) 1 seed sown as wr. g. gave rise to smooth green only.

(*b*) and (*c*) illustrate the fact already stated that smooth and wrinkled seeds are not always to be distinguished with certainty from their external appearance. (*a*) may be due to the inheritance of the property of turning yellow as the result of exposure. Taking into consideration the sources of error and the poverty of the crop, the sampling may be said to have been carried out with a fair degree of accuracy. The error is not sufficient to affect the general conformity with Mendelian expectation.

2. *Telephone* × *Native pea No.* 1.—The Mendelian constitution as regards cotyledon characters was determined in the case of the following plants of F_2 :—

Number.	Character of F_2 Seed.	F_3 Seeds born on F_2 Plant.				Constitution of Parent F_2.
		sm. y.	sm. g.	wr. y.	wr. g.	
621.1.1	sm. y.	9	5	3	1	AaBb
.2†	sm. g.	—	66	—	—	Ab
.3	,,	—	34	—	10	Aab
.4	,,	—	45	—	11	Aab
.5	,,	—	19	—	6	Aab
.6	wr. y.	—	—	—	29	ab
621.2.1	sm. y.	45	27	10	3	AaBb
.2†	wr. y.	28	—	10	—	AaB!(*c*)
623.1.1	sm. y.	31	7	9	—	AaBb
.2	,,	39	—	6	—	AaB
.3	,,	38	—	—	—	AB
.4	,,	21	4	—	—	ABb
.5	,,	19	—	12	—	AaB
.6	,,	7	1	—	—	ABb
.7	,,	17	3	—	—	ABb
.8	,,	38	11	—	—	ABb
.9†	wr. y.	—	—	97	29	aBb
.10	,,	—	—	38	—	aB
.11†	,,	—	—	62	—	aB
623.2.1	sm. y.	44	10	—	—	ABb
.2†	sm. g.	—	16	—	7	Aab
.3†	wr. y.	—	—	58	17	aBb
623.4.1†	sm. y.	55	20	23	5	AaBb
.2	,,	48	13	17	7	AaBb
.3†	sm. g.	52	12	18	7	AaBb!(*a*)
.4	wr. y.	—	—	74	27	aBb
.5	,,	53	22	17	9	AaBb!(*b*)
623.5.1	sm. y.	46	15	14	5	AaBb
.2	,,	36	—	15	—	AaB
.3	,,	35	12	11	3	AaBb
.4	,,	100	—	—	—	AB
.5†	,,	162	—	51	—	AaB
623.5.6	sm. g.	—	38	—	13	Aab
.7	,,	—	29	—	13	Aab
.8	,,	—	20	—	—	Ab
.9†	wr. g.	—	—	1!	49	ab
634.1.1	sm. y.	19	5	—	—	ABb
.2	,,	9	4	—	—	ABb
.3	,,	18	4	4	3	AaBb
.4	,,	27	—	9	—	AaB

Number.	Character of F² Seed.	F_3 Seeds born on F_2 Plant.				Constitution of Parent F_2.
		sm. y.	sm. g.	wr. y.	wr. g.	
.5	sm. g.	—	20	2	9	Aab
.6	,,	—	30	—	—	Ab
.7	,,	—	29	—	13	Aab
.8	wr. y.	—	—	18	2	aBb
.9	,,	—	—	51	—	aB
.10	,,	—	—	79	21	aBb
.11	,,	—	—	3!	18	ab!(*d*)
634.2.1	sm. y.	41	11	10	3	AaBb
.2	,,	7	3	2	—	AaBb
.3	,,	25	6	5	6	AaBb
.4	,,	15	7	—	—	ABb
.5	,,	12	8	7	2	AaBb
.6	,,	19	6	—	—	ABb
.7	sm. g.	—	53	—	20	Aab
.8	wr. y.	—	—	29	9	aBb

Summing up as in the previous case, we have :—

Parent Seed.	Mendelian constitution of Parent.									Total.
	AaBb.	AaB.	Aab.	ABb.	aBb.	AB.	Ab.	aB.	ab.	
Sm. y. ..	12	5	—	8	—	2	—	—	—	27
Sm g. ..	(1)	—	9	—	—	—	3	—	—	13
Wr. y. ..	(1)	(1)	—	—	6	—	—	3	(1)	12
Wr. g. ..	—	—	—	—	—	—	—	—	2	2
Total ..	14	6	9	8	6	2	3		3	54

Four unconformable cases appear, namely :—

(*a*) 1 seed sown as sm. g. gave rise to all four types.

(*b*) 1 seed sown as wr. y. gave rise to all four types.

(*c*) 1 seed sown as wr. y. gave rise to sm. y. and wr. y. seeds.

(*d*) 1 seed sown as wr. y. gave rise to wr. g. seeds only.

(*b*), (*c*), and (*d*) may be accounted for as in the previous instance. Case (*a*) remains, and in this instance I am inclined to believe that the plant may have been mistaken in gathering ; and this is the more likely because sm. g. came next to sm. y. in my system of sowing, so that if germination took place very obliquely it is possible that the seedling may have come up on the wrong side of the partition dividing these groups.

The crop obtained in this instance was so far satisfactory that it is worth while to sum up the total proportions of seeds produced by the plants of different constitutions. Thus the 14 AaBb plants bore altogether the following seeds :—

Total 846—sm. y. 477; sm. g. 165; wr. y. 150; wr. g. 54. The expectation being for 848—sm. y. 477; sm. g. 159; wr. y. 159; wr. g. 53.

The 6 AaB plants produced the following : sm. y. 311; wr. y. 103.

The 9 Aab plants produced the following : sm. g. 283; wr. g. 104.

The 8 ABb plants produced the following : sm. y. 189; sm. g. 51.

The 6 aBb plants produced the following : wr. y. 355; wr. g. 105.

All four cases together give the proportion 1,138 : 363 or 75·8 : 24·2.

A further generation was grown from the seeds (F_3) of those plants which are distinguished by a † in the preceding table; with the following results :—

621.1.1 sm. g. seeds only. 15 plants bore 440 seeds—all sm. g. (F_4).

621.2.2. (a) sm. y. seeds gave rise to 8 plants, of these, 3 bore only sm. y. seeds 43 in number; 5 bore sm. y. and wr. y. seeds in the proportion 89 : 31.

(b) wr. y. seeds : 5 plants with 96 seeds—all wr. y.

623.1.9. (a) wr. y. seeds—22 plants, 4 with 140 wr. y. only; and 18 with 358 wr. y.: 120 wr. g.

(b) wr. g. seeds : 15 plants with 380 seeds—all wr. g.

623.1.11. wr. y. seeds only : 16 plants with 273 wr. y. seeds.

623.2.3. (a) wr. y. seeds : 8 plants, 7 with wr. y. only—81 seeds, and 1 with 10 wr. y. : 4 wr. g.

(b) wr. g. seeds : 3 plants with 41 wr. g. seeds only.

623.4.1. (a) sm. y. seeds gave rise to 20 plants :—

(a1) 10 plants with 97 sm. y., 28 sm. g., 37 wr.y., 14 wr. g.

(a2) 6 plants with sm. y. and sm. g. seeds : 100 : 28.

(a3) 3 plants with sm. y. and wr. y. seeds : 23 : 8.

(a4) 1 plant with 9 sm. y. seeds only.

(b) sm. g. seeds—8 plants : 4 with 60 sm. g. seeds only, and 4 with 58 sm. g. : 25 wr. g.

(c) wr. y. seeds—7 plants : 2 with 57 wr. y. seeds only, and 5 with 56 wr. y. : 28 wr. g.

(d) wr. g. seeds—3 plants : 2 with 35 wr. g. only, and 1 with 19 sm. g. only. (c. p. below.)

623.4.3. (a) sm. y. seeds gave rise to 14 plants :—

(a1) 7 plants with 133 sm. y., 50 sm. g., 48 wr. y., and 22 wr. g.

(a2) 3 plants with sm. y. and sm. g. seeds : 52 : 25.

(a3) 4 plants with sm. y. and wr. y. seeds : 85 : 34.

(b) sm. g. seeds—8 plants : 3 with 105 sm. g. seeds only, and 5 with 102 sm. g. : 42 wr. g.

(c) wr. y. seeds—10 plants : 1 with 26 wr. y. only, and 9 with 178 wr. y., 53 wr. g.

(d) wr. g. seeds—3 plants with 100 wr. g. seeds only.

623.5.5. (a) sm. y. seeds gave rise to 43 plants :—16 with 323 sm. y. seeds only, and 27 with 427 sm. y. : 140 wr. y.

(b) wr. y. seeds—30 plants with 811 wr. y. seeds only.

623.5.9. wr. g. seeds only gave rise to 20 plants with 248 wr. g. seeds.

The unexpected occurred in a single case only, in which a supposed wr. g. seed of No. 623.4.1 turned out to have been really sm. g., there being thus 1 error among 249 cases of F_3 plants, all the rest of which follow exactly the Mendelian expectation.

4.—Telephone crossed with Ringleader.

A.—*The Parent Types have already been described.*

B.—*The Cross-bred Forms.*

Stated in brief the result of the present crosses was to confirm exactly Mendel's description of the effect of crossing a wrinkled green pea with a smooth yellow one.

1. *Telephone* × *Ringleader*.—15 pollinations resulted in the production of 12 pods containing 42 seeds, all smooth and yellow, though resembling in general shape the smooth seeds of Telegraph, or those of Telephone "filled out" so as to do away with the wrinkles.

2. *Ringleader* × *Telephone*.—4 pollinations : 2 pods with 2 seeds in each. These exactly resembled the normal seeds of the plants which bore them.

C.—*The Offspring of Cross-bred Plants*, F_2.

1. *Telephone* × *Ringleader*.—The seeds borne on the various plants were counted into the following groups :—

No.	sm. y.	sm. g.	wr. y.	wr. g.
428.1	15	3	6	1
.2	6	3	6	2
429.1	13	6	8	—
.2 & 3	15	8	9	2
430.1	3	4	2	2
.2	10	2	3	—
.3	10	1	2	1
431.1	11	5	3	2
.2	8	3	1	—
432.1	7	5	1	—
433.1	13	1	—	—
.2	7	2	2	—
.3	3	5	1	—
.4	5	3	2	2
.5	6	2	2	1
434.1	5	3	4	2
.2	7	2	3	—
.3	4	5	2	—
.4	3	3	2	—
.5	3	6	1	1
443.1	6	4	1	1
.2	3	3	4	1
.3	11	1	2	—
447.1	6	1	—	—
.2	3	1	2	2
452.1	3	1	2	—
.2	6	1	3	—
.3	6	1	1	1
457.1	13	5	5	1
.2	3	1	1	2
458.1	3	2	3	1
.2	7	2	1	1
Total	224	95	85	26

Sm. : wr. = 319 : 111 ; y. : g. = 309 : 121.

This generation produced fine large seeds of nearly the Telephone type throughout. Green and yellow seeds were always quite distinct, but smooth and wrinkled were rather more difficult to distinguish, and there was a slight doubt in one or two cases.

In the above cases as in others, a Mendelian total was arrived at when a sufficient number of plants were taken, in spite of the very small samples which individual plants afforded.

In a further generation the following figures were obtained :—

Number.	Character of F_2 Seed.	F_3 Seeds born on F_2 Plant.				Constitution of Parent F_2.
		sm. y.	sm. g.	wr. y.	wr. g.	
428.1.1	sm. y.	22	12	—	—	ABb
.2	,,	4	2	—	1	ABb
.3	,,	9	3	5	1	AaBb
.4	,,	38	—	—	—	AB
.5	,,	54	—	—	—	AB
.6	,,	3	—	—	—	?
.7	,,	6	3	—	—	ABb
.8	,,	31	—	—	—	AB
.9	,,	14	5	3	1	AaBb
.10	wr. y.	—	—	53	—	aB
428.2.1	sm. y.	41	—	—	—	AB
.2	,,	15	7	—	—	ABb
.3	,,	28	7	6	1	AaBb
.4	,,	49	—	—	—	AB
.5	wr. y.	—	—	21	8	aBb
.6	,,	—	—	13	3	aBb
.7	,,	—	—	50	17	aBb
.8	wr. g.	—	—	—	72	ab
429.1.1	sm. y.	42	—	—	—	AB
.2	,,	5	1	1	1	AaBb
.3	,,	17	—	6	—	AaB
.4	,,	35	—	—	—	AB
.5	,,	9	3	—	3	AaBb
.6	,,	10	—	1	—	AaB ?
.7	sm. g.	—	15	—	2	Aab
.8	,,	—	17	—	4	Aab
.9	,,	—	13	—	4	Aab
.10	wr. y.	—	—	39	—	aB
.11	,,	—	—	34	14	aBb
.12	,,	—	—	14	3	aBb
433.1.1	sm. y.	13	8	10	3	AaBb
.2	,,	25	4	5	1	AaBb
.3	,,	13	4	8	3	AaBb
.4	,,	18	2	1	5	AaBb
.5	,,	14	5	6	—	AaBb
.6	,,	32	3	—	—	ABb
.7	,,	5	—	3	—	AaB ?
.8	,,	13	11	—	—	ABb
.9	,,	18	—	5	—	AaB
433.2.1	,,	23	10	9	3	AaBb
.2	,,	3	—	4	—	AaBb
.3	,,	13	5	3	4	AaB
.4	wr. y.	—	—	36	17	aBb
434.1.1	sm. y.	33	—	1	—	AB
457.1.1	,,	38	8	10	5	AaBb
.2	,,	17	8	—	—	ABb
.3	wr. g.	—	—	—	34	ab

The result may be thus briefly summarized :—

Parent Seed.	Mendelian Constitution of Parent.									Total.
	AaBb.	AaB.	Aab.	ABb.	aBb.	AB.	Ab.	aB.	ab.	
Sm. y. ..	14	6	—	6	—	7	—	—	—	33
Sm. g. ..	—	—	3	—	—	—	—	—	—	3
Wr. y. ..	—	—	—	—	6	—	—	2	—	8
Wr. g. ..	—	—	—	—	—	—	—	—	2	2

5.—Native Pea No. 1 crossed with French Sugar Pea.

A.—*Description of Parents.*

Sutton's "*French Sugar Pea*" is described on the package as being on the average 5 feet high. The sample consisted of very large seeds, irregular in outline and slightly wrinkled (dimpled); they were slightly elongated and distinctly flattened from side to side. The starch grains were of the "round" type and the cotyledons were bright yellow in colour. The testa was quite opaque and of a colour varying from gray to orange-brown, and was sprinkled with purple or blackish-violet dots. On keeping, the gray testa showed a gradual change through orange to dark brown; so that in two years all the seeds preserved were of this colour and were then no longer capable of germination.

As grown at Peradeniya, the plants, under favourable conditions, reached a height of quite 7 feet; the usual number of internodes was 30, and the average length of an internode nearly three inches.

The stems were stout and branches were usually absent. The stems of young seedlings showed a red pigmentation at an early age, and a reddish purple patch appeared in the axil of each leaf. The flowers exhibited a red standard and purple wings.

The seeds resembled those of the original sample in size and form. The colour of the testa when the seeds were freshly gathered was nearly always greenish-gray; but some of the seeds in the lower pods usually showed signs of turning orange. Dark purple dots appeared upon all of them. The pods when fresh were very large, often containing eight or nine seeds and being moreover particularly wide ; when dry they were deeply constricted between the seeds and had a very shrivelled appearance, the parchment layer being quite wanting.

The first flower appeared upon the plants about 56 days after sowing and the seeds were dry some forty days later.

B.—*The Cross-bred Forms.*

1. *Native pea No.* 1 × *French sugar pea.*—From 18 pollinations there resulted 6 pods which were gathered on January 30th, 1903. They contained 26 seeds which exactly resembled those produced upon the same plants by self-fertilization. The average longest diameter of these seeds was 6·4 mm., which is almost exactly equal to the mean length of a sample of over 2,000 seeds of No. 1 which were accurately measured for another purpose.

Sixteen of these seeds were sown on May 2, and all of them germinated. The following table shows some of the characters of 14 plants which were taken up on July 30 :—

Number.	Height in Inches.	Number of Nodes.	Average Length of an Internode.	Number of Branches.	Pods.	Seeds.	Width of Pod in mm.
391·1	50	.	·	—	1	2	16
·2	55	.	·	—	3	6	15
·3	71	29	2·4	1	9	28	19
·4	74	31	2·4	2	8	29	18
·5	73	.	·	2	8	24	18
·6	82	35	2·3	2	8	26	18
393·1	94	33	2·8	2	9	34	18
·2	102	34	3·0	3	11	44	18
·3	79	34	2·3	1	9	31	18
·4	75	.	·	2	7	25	18
·5	.	.	·	1	5	16	17
394·1	80	25	3·2	1	8	21	15
·2	82	30	2·7	3	10	28	16
·3	95	33	2·9	3	10	26	17

The axils and flowers were coloured like those of Fr. sug. The pods were nearly of the shape of those of No. 1, but were much larger. In certain areas of the pods traces of a want of the parchment layer could be detected, but these areas were small and the pods were fully inflated.

The colour of the testa was rather pale gray, with a tendency to become yellow in weathered pods. All the testas were dotted with purple—perhaps not quite so strongly as those of Fr. sug. In shape and size the seeds were intermediate and all of them were well dimpled.

The bad effects of bright sunshine alternating with showers of rain was very marked in the case of these plants, the stipules being much blistered and damaged in this way.

2. *French sugar pea* × *Native pea No.* 1.—The reciprocal cross was made under unfavourable conditions in October, 1902. Out of seven crosses attempted three were successful with 8 seeds as the result. These were sown on December 22, the first flowers appeared after 53 days and ripe seeds were gathered from 5 plants on March 18, 1903.

No.	Height.	Nodes.	Average Length of Internode.	Branches.	Pods.	Seeds.
291·1	62	31	2·0	—	7	25
292·1	46	25	1·9	—	3	8
·2	68	31	2·2	3	10	37
322·1	72	32	2·2	—	5	18
·2	62	30	2.1	—	4	10

The more stunted habit of these plants is probably to be associated with the drier season in which they grew ; and the absence of branches upon four out of five of them may perhaps be attributed to the same cause. In all other respects these plants resembled those derived from the reciprocal cross.

C.—*The Second and Third Generations from the Cross.*

A somewhat full account of the behaviour of seed characters in these generations has been given in a previous paper, page 328. This may be here supplemented by the following table containing a *resumé* of the characters of the plants grown in F_2 and of some of those of their offspring in F_3.

No.	F₂. Height.	Number of Nodes.	Average Length of Internode.	Number of Branches.	Pods.	Seeds.	Pod P. or S.	Pod Width.	Colour of Testa.	Surface of Seed.	Number of Seeds Sown.	Number of Plants Examined in F_3.	F_3. Plants with Pods. W	N	P	S	Plants with Seeds. p	f	w
391.3.1	72	23	3·1	1	3	17	P	N	p	d	—	—	—	—	—	—	—	—	—
2	108	37	2·9	3	12	60	P	N	p	d	25	20	—	20	20	—	15	5	—
3	94	35	2·7	2	19	60	P	N	p	d	25	24	—	24	19	5	14	4	6
4	88	33	2·7	3	16	63	P	N	p	d	30	30	—	30	25	5	19	5	6
5	80	31	2·6	—	10	30	P	N	w	s	—	—	—	—	—	—	—	—	—
6	104	41	2·5	2	13	66	P	W	p	d	30	20	?	?	13	7	11	—	—
7	95	35	2·7	—	6	30	P	W	p	d	—	—	—	—	—	—	—	—	—
8	94	35	2·7	1	15	54	P	N	f	d	25	25	—	25	21	4	—	20	5
9	99	37	2·7	—	10	28	S	W	w	s	—	—	—	—	—	—	—	—	—
10	96	33	2·9	1	14	42	P	W	p	d	—	—	—	—	—	—	—	—	—
11	100	38	2·6	3	25	104	S	W	p	d	—	—	—	—	—	—	—	—	—
12	—	—	—	1	14	42	S	W	p	d	20	14	14	—	—	14	7	3	4
13	97	36	2·7	3	13	48	P	W	f	d	25	18	?	?	16	2	—	18	—
14	106	38	2·8	3	11	45	S	W	p	d	20	16	*	*	—	16	16	—	—
15	85	27	3·1	—	3	10	P	N	f	d	—	—	—	—	—	—	—	—	—
16	100	—	—	1	8	40	P	M	p	d	20	12	*	*	5	7	7	3	—
17	—	—	—	—	5	13	S	W	w	s	—	—	—	—	—	—	—	—	—
18	102	35	2·9	—	5	21	S	W	p	d	—	—	—	—	—	—	—	—	—
19	97	36	2·7	3	15	57	S	W	p	d	25	12	?	?	—	12	7	4	1

No.	F_2. Height.	Number of Nodes.	Average Length of Internode.	Number of Branches.	Pods.	Seeds.	Pod P. or S.	Pod Width.	Colour of Testa.	Surface of Seed.	Number of Seeds Sown.	Number of Plants Examined in F_3.	F_3. Plants with Pods. W	N	P	S	Plants with Seeds. p	f	w
20	103	40	2·6	2	20	83	P	N	p	d	40	36	—	—	36	—	27	9	—
21	99	34	2·9	1	5	33	P	W	p	d	—	—	—	—	—	—	—	—	—
22	109	39	2·8	3	14	58	S	W	p	d	30	16	?	?	—	16	12	4	—
23	95	32	3·0	—	4	22	P	W	f	d	20	8	8	—	7	1	—	8	—
24	—	—	—	—	3	6	P	W	p	d	—	—	—	—	—	—	—	—	—
25	—	—	—	—	2	10	P	N	f	d	—	—	—	—	—	—	—	—	—
26	88	—	—	2	4	20	P	W	p	d	—	—	—	—	—	—	—	—	—
391, 4, 5, and 6, 1	82	27	3·0	1	16	51	S	W	w	s	25	20	*	*	—	20	—	—	20
2	80	—	—	—	5	21	P	N	f	d	—	—	—	—	—	—	—	—	—
3	96	33	2·9	2	8	32	S	W	w	s	20	15	15	—	—	15	—	—	15
4	103	34	3·0	2	10	41	P	W	p	d	20	14	10	4	12	2	11	—	3
5	104	36	2·9	1	10	33	S	W	w	s	—	—	—	—	—	—	—	—	—
6	102	33	3·1	1	13	49	P	W	p	d	25	19	19	—	19	—	10	3	6
7	90	34	2·6	—	10	33	S	W	w	s	—	—	—	—	—	—	—	—	—
8	96	32	3·0	1	7	33	P	W	p	d	—	—	—	—	—	—	—	—	—
9	86	30	2·9	1	13	40	P	W	p	d	20	19	*	*	15	4	14	2	3
10	84	31	2·7	1	12	45	P	W	p	d	20	19	*	*	16	3	9	5	5
11	87	26	3·5	—	2	11	P	W	p	d	—	—	—	—	—	—	—	—	—

12	95	35	2·7	1	11	33	P	W	w	s	20	14	*	*	10	4	—	—	14
13	—	—	—	3	13	45	P	W	w	s	20	11	*	*	9	2	—	—	11
14	96	28	3·4	—	8	29	S	W	f	d	20	18	13	5	—	18	—	18	—
15	88	33	2·7	2	18	57	P	W	p	d	30	28	23	5	23	5	16	2	10
16	92	33	2·8	1	8	40	P	W	p	d	20	9	*	*	9	—	5	2	2
17	96	35	2·7	1	7	32	P	W	p	d	—	—	—	—	—	—	—	—	—
18	106	35	3·0	—	10	33	P	W	p	d	—	—	—	—	—	—	—	—	—
19	108	39	2·9	2	18	83	P	N	p	d	40	25	?	*	25	—	18	5	2
20	99	35	2·8	3	18	75	P	W	p	d	30	21	*	*	15	6	14	—	7
21	98	38	2·6	3	18	60	P	N	p	d	30	14	—	14	14	—	7	5	2
22	98	34	2·9	2	14	60	P	M	f	d	30	25	*	*	17	5	—	15	10
23	94	33	2·8	—	5	27	P	W	f	d	—	—	—	—	—	—	—	—	—
24	113	39	2·9	3	11	47	P	M	p	d	25	24	16	8	24	—	15	2	7
25	84	23	3·6	—	3	10	P	W	p	d	—	—	—	—	—	—	—	—	—
26	109	40	2·7	2	13	71	P	W	p	d	30	23	*	*	22	4	20	—	6
27	103	33	3·1	—	6	22	P	W	w	s	—	—	—	—	—	—	—	—	—
28	87	29	3·0	—	3	10	S	W	p	d	—	—	—	—	—	—	—	—	—
29	105	36	2·9	—	8	34	S	W	f	d	—	—	—	—	—	—	—	—	—
30	101	37	2·7	2	13	60	S	W	p	d	30	19	16	3	—	19	10	4	5
31	86	34	2·5	1	13	58	P	W	f	d	25	20	*	?	15	5	—	18	2
32	71	26	2·7	—	3	11	P	W	w	s	—	—	—	—	—	—	—	—	—
33	92	34	2·7	3	30	94	P	N	p	d	40	34	—	34	34	—	26	8	—
34	97	38	2·6	2	9	40	S	W	f	d	20	12	12	—	—	12	—	12	—
35	82	30	2·7	—	6	19	P	N	w	s	10	10	—	10	10	—	—	—	10
36	85	31	2·7	—	4	12	S	W	w	s	—	—	—	—	—	—	—	—	—
37	90	30	3·0	—	6	16	P	W	p	d	—	—	—	—	—	—	—	—	—
38	88	28	3·1	3	7	22	S	W	w	s	—	—	—	—	—	—	—	—	—
39	75	—	—	—	5	13	S	W	w	s	—	—	—	—	—	—	—	—	—
40	98	31	3·2	—	11	39	P	W	w	s	10	10	*	*	10	—	—	—	10
41	110	39	2·7	2	12	65	P	N	p	d	20	20	*	*	18	2	20	—	—
42	84	32	2·6	2	19	62	P	W	w	s	30	19	*	*	19	—	—	—	19

No.	F₂.										Number of Seeds Sown.	Number of Plants Examined in F_3.	F_3.						
	Height.	Number of Nodes.	Average Length of Internode.	Number of Branches.	Pods.	Seeds.	Pod P. or S.	Pod Width.	Colour of Testa.	Surface of Seed.			Plants with Pods.				Plants with Seeds.		
43	85	25	3·4	—	3	10	P	W	p	d	—	—	—	—	—	—	—	—	—
44	96	33	2·9	—	10	41	P	N	p	d	20	18	—	18	18	—	13	—	5
45	105	37	2·8	1	12	57	P	N	p	d	—	—	—	—	—	—	—	—	—
46	108	42	2·6	1	12	40	P	W	p	d	20	18	18	—	15	3	9	4	5
47	—	—	—	2	14	54	S	W	f	d	25	19	19	—	—	19	—	16	3
48	—	—	—	2	7	43	P	W	p	d	20	18	18	—	18	—	6	5	7
49	96	31	3·1	2	11	47	S	N	p	d	20	19	*	*	—	19	18	—	1
50	94	34	2·8	2	7	27	P	W	w	s	—	—	—	—	—	—	—	—	—
51	94	25	3·8	—	3	8	P	—	f	d	—	—	—	—	—	—	—	—	—
52	67	22	3·0	—	3	8	S	W	f	d	—	—	—	—	—	—	—	—	—
53	93	30	3·1	—	2	9	P	W	p	d	—	—	—	—	—	—	—	—	—
54	—	—	—	—	—	40	P	N	p	d	—	—	—	—	—	—	—	—	—
55	114	40	2·9	5	15	58	P	W	p	d	—	—	—	—	—	—	—	—	—
56	94	37	2·5	5	25	103	S	W	p	d	—	—	—	—	—	—	—	—	—
57	120	42	2·9	2	12	42	P	W	p	d	20	3	3	—	2	1	2	1	—
58	125	49	2·6	3	14	60	S	W	p	d	—	—	—	—	—	—	—	—	—

In the above table P = inflated and S = soft or constricted pods; W = wide, M = mid, and N = narrow pods. p denotes purple-spotted, f grey, and w white testa; d indicates dimpled, and s smooth or slightly pitted seeds. Height and average length of internodes are given in inches.

** Plants with wide and others with narrow pods were present, but they could not be separated into two distinct groups owing to the existence of intermediates.

Considering now the various characters summarized in this table, we observe that the average length of the internodes shows a fairly continuous variation ; and we may remember that this length was not very different in the two parental strains.

Width of pod is a character which almost certainly exhibits Mendelian segregation in spite of a good deal of apparently indefinite variation. Unfortunately no actual measurements were made in F_2, but the plants with distinctly narrower pods were separated by eye from the remainder which had wider pods. There were 19 of the former and 65 of the latter. Out of 13 of the former, the seeds of which were sown, 9 plants produced only offspring with narrow pods (13-16 mm.), whilst the remaining 4 plants appeared to have been heterozygotes with exceptionally narrow pods. Out of the 31 plants with wider pods which were examined none gave rise only to offspring with narrow pods. Nine gave rise to offspring all wide podded (17 mm. and upwards), whilst the remaining 22 plants gave rise to both kinds of offspring. It seems clear therefore that Mendel's law is here followed in spite of much variability and in spite of the intermediate position of the heterozygote.

As a general rule wide pods contained flattened seeds and narrow pods contained cubical or spherical seeds ; though in this point too there was a certain amount of variability. The only exceptions were a few cases in which seeds classed as round or cubical appeared in pods which were classed as wide. In such cases, when the seeds were grown, it appeared that the plants were heterozygotes in respect of pod width.

Seeds with white testas were usually smooth or slightly pitted, whereas coloured seeds were always markedly dimpled.

In the case of some of the above characters the distinction of the allelomorphs is certainly open to criticism. In such cases it is not absolutely proved that Mendel's law is followed, although the probability may be very great that this is so. In other cases the discontinuity is complete, and in these cases the evidence that Mendel's law is followed is complete also.

Thus, in the case of the presence or absence of a parchment layer in the pods, Mendel's results were fully confirmed, with the exception that dominance of the inflated pod was found to be not quite complete. As regards the allelomorphic characters gray and white colour of the testa the same thing is true. Purple spots appeared in addition on the testas in the case of three out of four of the plants which had a coloured testa, and the further behaviour of these characters entirely bears out the explanation given on page 331.

The presence of coloured flowers appears to be completely correlated with a coloured testa (greenish-gray) and with the presence of purple spots in the axils of the leaves. And with these characters the time of flowering is to some extent correlated. The evidence for this latter statement is given in the following table :—*

No.	In fl. May 25.		In fl. May 30.		In fl. June 4.		Total Gathered.	
	p.	w.	p.	w.	p.	w.	p.	w.
391.3.3	—	—	1	3	6	4	18	6
.4	14	4	18	6	24	6	24	6
.8	—	—	—	—	3	1	20	5
.12	—	—	3	2	8	3	10	4
.19	—	—	—	—	1	1	11	1
.22	—	—	2	3	4	5	12	5
391.4.4	—	1	—	3	4	3	11	3
.6	—	1	5	3	7	5	18	6
.9	6	3	9	3	15	3	16	3
.10	8	2	12	5	14	5	14	5
.15	3	2	12	8	15	10	18	10
.16	—	1	5	3	7	3	7	3
.19	—	—	—	—	—	—	23	2
.20	—	—	3	5	9	6	14	7
.21	1	1	5	1	9	2	12	2
.22	—	—	—	4	4	8	15	10
.24	—	2	4	4	8	4	17	7
.26	1	4	8	8	15	8	20	8
.30	—	4	4	4	9	5	14	5
.31	1	1	7	2	12	2	18	2
.44	—	—	1	3	3	5	13	5
.46	—	—	2	1	4	2	13	5
.47	—	3	5	3	10	3	16	3
.48	—	—	1	5	4	9	11	9
.49	—	—	—	—	—	1	18	1
Total ...	34	29	107	79	175	104	383	123
	1.17 : 1		1.35 : 1		1.68 : 1		313 : 1	

* p = plants with coloured flowers; w = plants with white flowers.

6.—Native Pea No. 2 crossed with Satisfaction.

A.—*Description of Parents.*

1. *Satisfaction*, as obtained from Messrs. Sutton, is described on the package as being 3 feet in average height. "Habit robust and endures drought well. Pods straight and broad and closely filled with very large peas."

The original sample consisted of very large seeds with yellow cotyledons, much wrinkled. The testas were slightly greenish or yellowish and not very transparent.

As grown at Peradeniya the plants were always of a very uniform height, the extreme range of variation being from about 3 feet 6 inches to about 5 feet. Average 4 feet 6 inches (137 cm.). The average number of nodes was 31; the average length of an internode being therefore 1·74 in. (44 mm.). The average width of a pod was 22 mm.

The seeds were large and thoroughly wrinkled, the starch grains being of the type characteristic of wrinkled seeds. Their colour was the rather pale shade of yellow which appears to be often associated with the wrinkled character.* The testas were white, usually without any trace of pigment, and a little less opaque than those of the original sample.

Seeds gathered from my own plants and ripened in February germinated without exception when sown the following April, and scarcely any plants were lost. The variety, in fact, stood the climate of Peradeniya better at all times of year, and gave a better crop than any other English kind which was examined.

2. *Native pea No.* 2.—The average height was less than three feet, but differed a good deal at different seasons. Average number of nodes 24 and average length of an internode about $1\frac{1}{2}$ in. (3·8 cm.). Width of pod on the average 10 mm. Main stem thin; often with 3–5 branches at the base, which attain an equal height. Flowers less than half the size of those of Satisfaction; the standard pinkish-red in colour, the wings purple and changing from a reddish to a bluish purple as the flowers get older. Seeds very small, quite

* *Cf.* the account of Telephone crosses above; also Hurst, in Journ. Roy. Hort. Soc., 1904.

smooth, and nearly spherical, but being closely packed in the pod they exhibit a certain squareness of outline. Cotyledons yellow; starch grains of the round type. The testa shows fine dots of a deep purplish colour and, in addition, a marbling of brown on a pale greenish-yellow ground. The purple colouration is produced by a pigment dissolved in the sap of certain cells immediately underlying the outermost layer of the testa. The brown colour is almost or quite confined to the walls of the I-shaped cells of the outermost layer. The greenish colour seems to be a solid pigment deposited in all or nearly all the cells of the testa.

I have received a closely similar pea from the Superintendent of the Calcutta Botanic Gardens under the name of *Pisum quadratum*. The habit of the plants is slightly different, but in other respects they closely resemble one another. Certainly no one would at first sight place these plants in the same species as the ordinary forms of *Pisum sativum* grown in Europe. The former have in comparison a primitive and wild appearance, and the suggestion that they may lie somewhere near the original ancestor of European cultivated peas is supported by the fact presently to be described in greater detail, that on crossing with the white-coated form Satisfaction there were obtained in F_2 all the best known types of testas to be found in cultivated peas.

B.—*The Cross-bred Forms.*

1. *Native pea No.* 2 × *Satisfaction.*—Only one cross (No. 440, made in January, 1903) was successful; and various accidents prevented me from obtaining further crosses. Three seeds were produced, quite indistinguishable from the other seeds of the same plant so far as appearance was concerned. The seeds were sown on May 2, but only one plant produced seed. This plant was 70 inches in height and had 31 nodes. The average width of its 4 pods was 14 mm., and these contained altogether 8 seeds. The plant and its seeds resembled those produced upon the plants of the reciprocal cross, and they may be described together.

2. *Satisfaction* × *Native pea No.* 2.—Two successful crosses gave rise to 6 seeds which were gathered on February 17, 1903. These seeds closely resembled those of Satisfaction except in being filled

out so as to have a smooth surface; with the exception of a slight dimple on each side, such as was often observed in "round" seeds grown in Ceylon. The seeds were sown on May 2, and 3 plants bearing seeds were taken up on July 27. The length of life of these plants was therefore intermediate, but nearer to that of Satisfaction. The following table shows some of the characters of these plants :—

No. of Cross.	Height.	Nodes.	Pods.	Seeds.	Width of Pod in mm.	Seeds.	
						Dimpled.	Wrinkled.
440	70	31	4	8	14	8	—
439	75	30	5	15	14	12	3
441.1	79	31	2	5	15	5	—
441.2	74	31	4	8	14	6	2

None of the plants produced any branches. The average length of an internode was 2·4 in. (6·1 cm.), greatly exceeding that characteristic of either parent. The number of internodes was practically the same as in Satisfaction, but the plants were much taller. Width of pod was intermediate.

As regards the shape of the seeds we have some interesting points to consider, for all were more or less wrinkled. There were considerable differences in the degree of wrinkling, and in the case of two plants it was possible to distinguish between a group of very wrinkled seeds (5 in number) and a remaining group of 18 to which the term dimpled might better be applied. I could not satisfy myself that there were any of the truly wrinkled group upon the other two plants. The phenomenon is in agreement with a case described by Tschermak, who crossed a smooth coloured-coated pea with a smooth white-coated pea and in F_1 (of seed-coat—F_2 of cotyledons) obtained exclusively "slightly wrinkled" seeds. It appears that as a rule the dimpled character is correlated with the coloured coat, and in the present case this correlation would seem to have become restored as the result of the cross. My example is complicated by the fact that the white-coated pea used was wrinkled, so that in F_1 of seed-coat and F_2 of cotyledons there is expected a proportion of three dimpled to one wrinkled. And the evidence goes to show that this expectation was fulfilled, although no examination of starch grains was made for the reason that the seeds were required for sowing.*

In colour the testas of these peas closely resembled those of No. 2; but the ground colour was in all cases of a distinctly yellowish shade such as appeared only exceptionally in No. 2. On the whole we may fairly say that there was full dominance of the colour characters of the testa of No. 2. The flowers also and leaf axils were coloured like those of the parent. The form of the foliage was more or less intermediate.

C.—*The Subsequent Generations.*

In F_2 no distinction was to be recognized between the separate offspring of the above four plants. The 25 plants of this generation may therefore be described together.† The majority of the characters to be considered are epitomized in the following table :—

Number.	F_2. Height (Inches).	Number of Nodes.	Average Length of Internodes.	Branches.	Character of Testa.	Seeds Sown.	F_3. Plants Gathered.	m.p.	m.	p.	f.	w.	Plants with long Internodes.	Plants with short Internodes.
440 &.1	85	42	2·0	1	mp	50	36	26	5	5	—	—	*	.
441.2	90	31	2·9	2	p	20	9	—	—	9	—	—	*	*
.3	75	42	1·8	3	m	30	24	—	18	—	—	6	*	*
.4	83	41	2·0	8	mp	150	88	48	8	7	5	20	*	.
.5	20	17	1·2	—	w	3	3	—	—	—	—	3	.	*
.6	16	14	1·1	—	p	3	1	—	—	1	—	—	.	*
.7	24	20	1·2	—	f	20	18	—	—	—	18	—	.	*

m = marbled with brown; p = spotted with purple; f = grey with faint bluish dots; w = white.

* Such an examination was however applied to the seeds of a later generation, with results which fully confirm the conclusion here arrived at.

† As a matter of fact the offspring of the reciprocal crosses 440 and 441 could not be distinguished owing to the labels having been accidentally shifted.

Number.	F₂. Height (Inches).	Number of Nodes.	Average Length of Nodes.	Branches.	Character of Testa.	Seeds Sown.	F₃. Plants Gathered	m.p.	m.	p.	f.	w.	Plants with long Internodes.	Plantswith short Internodes.
.8	29	16	1·8	—	f	2	—	—	—	—	1	1	*	.
.9	107	47	2·3	5	w	40	—	.	.	.	.	.	*	.
.10	94	44	2·1	4	p	40	21	—	—	13	3	5	*	*
.11	95	37	2·6	9	mp	60	32	16	9	1	3	3	*	.
.12	110	41	2·7	6	w	40	4	—	—	—	—	4	*	*
.13	103	40	2·6	4	w	10	3	—	—	—	—	3	*	*
.14	70	29	2·4	—	mp	8	7	3	—	1	—	3	*	*
.15	104	42	2·5	5	mp	60	20	11	1	—	—	8	*	*
.16	62	54	1·1	5	mp	20	—	.	.	.	.	.	.	*
439.1	58	23	2·5	1	p	25	17	—	—	12	—	5	*	*
.2	49	18	2·7	—	p	10	2	—	—	2	—	—	*	.
.3	25	21	1·2	—	p	6	—	.	.	.		.	.	.
.4	80	43	1·9	20	mp	80	61	30	7	—	—	24	*	*
.5	78	37	2·1	4	mp	60	44	18	3	8	1	14	*	.
.6	tall				mp	110	66	34	16	—	—	16	*	*
.7	80	44	1·8	—	mp	8	7	5	2	—	—	—	*	.
.8	85	38	2·6	1	m	26	2	—	2	—	—	—	*	.
.9	dwa	rf			w	.	.	.	.	,	.	.	.	.

As regards habit there was a great deal of variation. Some of the plants were very robust, whilst others—dwarfs, which were soon overgrown by the former—were very feeble. If we consider the character average length of internodes, we find an obviously Mendelian behaviour.

Thus, in F_2 19 plants had internodes 1·8 to 2·9 inches in length, and 6 plants had internodes 1·0 to 1·2 inches in length.

The latter produced in F_3 exclusively offspring with an average length of internodes of less than 1·3 in. Of the former 9 produced only offspring with long internodes in F_3 (1·6 in. long and upwards), but in a few cases there were only one or two plants per parent, and some of them should therefore perhaps be added to the number of the heterozygotes, namely, 10 plants, which produced both offspring with long and with short internodes in F_3.

In F_3 the plants with long and those with short internodes were readily distinguishable two or three weeks after germination. At this time the former were, as a rule, quite twice as tall as the latter and perfectly distinct in appearance. The offspring of the 10 heterozygotes was as follows in F_3, the counting being made 18 days after germination. A considerable number of these plants subsequently perished from drought, and a few had already died since germination, the mortality being greater in the case of the dwarf form :—

No.	Tall.	Dwarf.	No.	Tall.	Dwarf.
439.1	12	5	440.10	28	4
.4	48	14	.12	23	8
.6	74	16	.13	5	4
440.2	5	4	.14	6	1
.3	22	3	.15	31	13

Total—245 tall to 72 dwarf, or 3·53 : 1. The two groups are unmistakably distinct, the dwarf forms having a much stiffer appearance and foliage somewhat darker than the tall.

Length of life was found to be a character quite independent of the above, and is one which may considerably modify the final height of the plant. Thus, in the case of No. 440·16 ; flowers did not appear before the 48th internode. The offspring of this plant, which resembled the parent, all fell victims to excessively wet weather before any flowers appeared ; most of them had by that time developed about 40 internodes. It is a remarkable fact that none of the tall or dwarf forms in F_2 and F_3 were in the least like either of the original parents, in both of which the internodes seemed to be of medium length. In F_1 there appeared a form with longer internodes than either parent, and in F_2 this form persisted as a dominant type, whilst a new recessive form appeared with shorter internodes than either parent.

As regards the shape of seeds in F_2 and F_3, the phenomena observed may be briefly summed up as follows :—Seeds with a coloured testa were dimpled or wrinkled according to Mendel's law, although the difficulty of exact discrimination made it impossible to ascertain the precise ratio in more than a few cases. Small seeds were as a rule less dimpled than large ones, so that some of the smallest of the coloured seeds were practically smooth in surface (or, on the other hand, quite wrinkled), though usually more or less square in outline. Even in the case of the largest seeds dimpled and wrinkled were usually quite distinguishable; and the point could be settled by cutting sections, when dimpled seeds were found to have starch grains of the "round" type. In other cases where the eye alone could not distinguish dimpled from wrinkled with certainty, the microscopic test was found to be conclusive.

Among the seeds with a white or nearly colourless testa, smooth and wrinkled cotyledons appeared in accordance with Mendelian expectation.* The above remarks apply without exception to F_2 and to all the seeds in F_3 which could be dried. Many of the F_3 plants were taken up in very wet weather, and in such cases it was impossible to discriminate between the shapes of the seeds.

The colour of the testa appeared to follow perfectly definite rules, some account of which has already been given in a previous paper (page 333), but the description needs elaborating in some respects. Twenty-five plants were raised in F_2, their seed-coat colours being as follows :—

Eleven plants (m. p. f.) showed testas coloured like No. 2, except that in some cases the ground colour was yellowish like that of the F_1 plants, whilst in others it was greenish like the parental strain.† The purple spots and the " maple " marking was clearly visible in all these cases.

Six plants (p. f.) resembled these in the ground colour of the testa and in the presence of purple spots, but the maple marks were quite wanting.

In two others (m. f.) the purple spots were wanting, but the maple marking was obviously present.

In two more (f.) both purple spots and maple marks were wanting, but the testas were obviously greenish and opaque.

* In F_2 all 4 plants with white testas had seeds exclusively smooth—DD—when the expectation was 1 DD : 2 DR : 1 RR. This was probably accidental, since in F_3, among the offspring of dimpled seeds, those with white coats showed the expected number of wrinkleds.

† The relative numbers of the two kinds were not counted in this or the next generation, and I do not think that they were always distinguishable.

All the above plants had coloured flowers and purple spots in the axils of the leaves. The four remaining plants had perfectly white flowers and the spots in the axils were wanting. Three of these plants had white testas like Satisfaction. In the fourth the colour was the same, but there appeared what can only be described as a kind of watermark, like the ghost of the maple pattern. It was quite distinctly visible in all the seeds of the plant.

In the remarks which follow concerning F_3, the same colours are denoted by the same letters. On white flowered plants the (invariably white-coated) seeds often showed the same maple watermark, but usually very indistinctly, and it could not always be traced in all the seeds of a plant even when some of them showed it. It seems clear that we have here a partial reappearance of the almost latent maple character, and in this case I should expect that on crossing such plants with a pure strain having pigmented testas, the full maple colour would make its appearance in some or all of the immediate offspring. It is hoped to test this conclusion by making such crosses during the present summer.*

It may tend towards clearness if I here set down at length the relative numbers of the different types of seeds which are to be expected in F_2 and F_3 on the hypothesis that the characters brown marbling (m) and purple spotting (p) can only appear in combination with the greenish or yellowish ground colour (f), but that in other respects Mendel's law is followed.

(1) Offspring of the forms showing all three colours (m. p. f.) :—

(*a*) 1 constant in F_3 (m. p. f.).
(*b*) 2 giving in F_3 (m. p. f.) and (m. f.).
(*c*) 2 giving in F_3 (m. p. f.) and (p. f.).
(*d*) 2 giving in F_3 (m. p. f.) and (w.).
(*e*) 4 giving in F_3 (m. p. f.), (m. f.), (p. f.), and (f.).
(*f*) 4 giving in F_3 (m. p. f.), (m. f.), and (w.).

* Note added July, 1905.—In a further generation (F_4), grown in England under good conditions, the distinction between plants bearing w and those bearing w (m) seeds was quite clear, and the inheritance was plainly Mendelian, w (m) being dominant to w. Crosses of the kind mentioned have been made in considerable numbers, and the result will appear next year.

(*g*) 4 giving in F_3 (m. p. f.), (p. f.), and (w.).
(*h*) 8 giving in F_3 (m. p. f.), (m. f.), (p. f.), (f.), and (w.).

(2) Offspring of the forms showing brown marbling (m. f.) :—
(*j*) 1 constant in F_3 (m. f.).
(*k*) 2 giving (m. f.) and (f.).
(*l*) 2 giving (m. f.) and (w.).
(*m*) 4 giving (m. f.), (f.), and (w.).

(3) Offspring of the forms showing purple spots (p. f.) :—
(*n*) 1 constant in F_3 (p. f.).
(*o*) 2 giving (p. f.) and (f.).
(*p*) 2 giving (p. f.) and (w.).
(*q*) 4 giving (p. f.), (f.), and (w.).

(4) Offspring of the form with simple coloured seeds (f.) :—
(*r*) 1 constant in F_3 (f.).
(*s*) 2 giving (f.) and (w.).

(5) Offspring of forms with a white testa (w.) :—
(*t*) 16 constant in F_3 (w.).

Thus 64 individuals of F_2 should include 19 forms of constitution. Out of the 25 plants obtained in F_2, 10 were found on examination of their offspring to have been of the following forms :—1 (*b*), 1 (*e*), 4 (*f*), 1 (*g*), 3 (*h*), 1 (*l*), 1 (*n*), 1 (*p*), 1 (*q*), 1 (*r*), 1 (*s*), and 3 (*t*), as may be seen on consulting the table. The remaining plants did not yield a sufficient number of offspring to allow of their character being determined. No unexpected type appeared among the whole series of 467 plants grown in F_3, and the proportions in which the visible types appeared were also in reasonable agreement with expectation.

Thus the total offspring of the 3 plants of type (*h*) was as follows :—

	Total.	(m.p.f.)	(m.f.)	(p.f.)	(f.)	(w.)
	169	82	20	21	9	37
Expectation	192	81	27	27	9	48

And the offspring of the 4 plants of type (*f*) were as follows :—

	Total.	(m.p.f.)	(m.f.)	(w.)
	147	75	24	48
Expectation	144	81	27	36

The agreement with theoretical expectation is so close that it appears reasonable to accept the hypothesis for the present. But it is hoped shortly to put it to the test by making crosses between the offspring of different types and a number of pure races.

7.—Other Crosses.

A number of further crosses were also made between the members of several different races of peas. These, so far as their decidedly feeble progeny in F_1 and F_2 allowed of estimating, afforded no exceptions to the ordinary Mendelian expectation as regards the allelomorphic characters which they exhibited, and which included representatives of cotyledon colour and shape, stature, inflation of pods, and colour of flowers and testa.

The following is a list of such crosses. None of the progeny showed much promise of developing into hardy strains and consequently none were grown after F_2.

Parents.	Number of Crosses Attempted.	Number Successful	Seeds Produced.	Characters Concerned.*
1.—No. 1 × Nonsuch ..	5	2	4	ABG x abg
2.—Earliest Blue × French Sugar ..	4	1	2	bcDg x BCdG
3.—French Sugar × Earliest Blue ..	2	2	3	BCdG x bcDg
4.—Satisfaction × French Sugar ..	4	4	11	D x d†
5.—No. 1 × Fillbasket..	7	5	16	B x b
6.—No. 1 × Earliest Blue ..	9	3	6	B x b
7.—Earliest Blue × No. 1	4	2	4	b x B
8.—No. 1 × Satisfaction	3	3	14	A x a
9.—No. 1 × Eclipse ..	2	1	3	B x b
10.—No. 1 × British Queen	3	1	6	A x a
11.—Satisfaction × Ringleader ..	1	1	4	a x A
12.—No. 2 × No. 1. ..	3	2	5	—

* A = smooth, a = wrinkled; B = yellow, b = green; C = testa grey, c = testa white; D = pod inflated, d = pod constricted; G = tall, g = dwarf.

† Development of the parchment layer decidedly intermediate in F_1, although the pods are obviously inflated.

Summary.

A somewhat complete summary of the more important of the facts dealt with in the present notice has already been given in a previous paper, see pages 308, 312, 328, 333; the account which follows deals chiefly with a few phenomena not previously referred to.

The result of the crosses made with Telegraph and Telephone was on the whole fully to confirm Mendel's account of the behaviour of cotyledon characters on crossing. In the crosses with Ringleader the agreement with expectation was complete; in the case of those with the small smooth yellow native pea (No. 1) a single absolute exception appeared in F_1, in which green appeared instead of the expected yellow. In F_2 and F_3 a few minor irregularities were observed, also in respect of colour, which are probably to be accounted for by imperfect ripening. In later generations the behaviour of these characters was more regular than in the earlier ones, and this is perhaps to be partly associated with the better health of the plants, but also, almost certainly, to an intensification of the characters following upon the cross. Nevertheless, even in F_2, when the total number of seeds born upon individual plants was often very small, totals closely approximating to Mendelian expectation were obtained when the figures for several plants were combined.

A summarized account of the crosses between French Sugar and No. 1 will be found on page 328 (example VI.). The colour characters of the testa gave in F_2 the proportion 9 : 3 : 4, already observed by Tschermak in several instances, but not described by him in terms of gametes. Other definite characters such as presence and absence of the parchment layer in the pod, follow Mendel's law, although dominance is not perfect in this case; and certain other less definite characters very probably behave in the same way.

The cross between No. 2 and Satisfaction, briefly described on page 333 (example VII.), was only represented by a few individuals in the earlier generations, but on account of its rather peculiar interest and because many of its offspring still survive for further experiment, it is here described at considerable length. The colour characters of the testa yield in F_2, almost certainly, the proportion 27 : 9 : 9 : 3 : 16, also observed by Tschermak in the case of certain flower colours of Matthiola, and an explanation of this proportion is attempted on the same lines as in the previous instance.

This cross seems also to afford an example of remarkable intensification of both the allelomorphic characters of the same pair, namely, tallness and dwarfness—the former in F_1, and both in F_2 and later generations. As regards shape of the seeds a complication is introduced by the appearance of the plant character, dimpled seeds, in the offspring of a cross between parents which showed the allelomorphic characters, smooth and wrinkled cotyledons respectively.

A few other crosses support Mendel's experiments and conclusions, which are indeed already sufficiently well established.

Cambridge, July, 1905.

Foliar Periodicity of Endemic and Indigenous Trees in Ceylon.

BY

HERBERT WRIGHT.

(*With plates XXV. to XXX.*)

A STUDY of the behaviour of plants in a tropical region where the conditions for growth are more favourable than in Europe has always attracted the attention of botanists, and since 1900 a considerable amount of time has been spent in studying the foliar periodicities in plant life with the object of tracing out some of the laws which govern these phenomena. There are several problems to consider, such as the relationship between the time, manner, and frequency of defoliation of trees in the tropics and in middle Europe; also how far the phenomena of leaf-fall and foliar renewal, in the tropics, are affected by external and internal forces, and to distinguish cases in which either or both of these factors are of importance.

The amount of variation to be met with in trees commonly deciduous in various parts of Ceylon, the relation of defoliation to transpiration, and the independent effects of heat, light, and moisture, are some of the problems which are here considered. The following synopsis will indicate the general arrangement of the present paper :—

1.—General.

2.—Periodicity in Growth.

Periodicity in temperate and tropical zones.

Periodicity of vegetation in Ceylon; herbaceous and shrubby.

Periodicity of trees in Ceylon.

Forest types.

Frequency of foliar activity.

[Annals of the Royal Botanic Gardens, Peradeniya, Vol. II., Part III., October, 1905.]

3.—Climate in Ceylon and Java.
4.—The Leafless Phase in the Tropics.
General characteristics.
Variation in different climates.
Parts of Ceylon.
Ceylon and Java; Peradeniya, Buitenzorg, and East Java.
Ceylon and Ursprung's species.
Variation in the same climate.
Variation in successive years.

5.—Transpiration in Ceylon.
General.
Periodicity and transpiration.
6.—The relative importance of the physical factors: temperature, rainfall, humidity, and light.
7.—External and Internal Factors.
8.—Advantages of Periodical Phenomena.
9.—Relation of Foliar, Floral, and Fruit Periodicities.
10.—Foliar Periodicity of Fossil Plants.
11.—Foliar Periodicity of Endemic Species.
12.—Foliar Periodicity of Indigenous Species.
13.—Ceylon Indigenous Species in India.

Sachs in his "Lectures on the Physiology of Plants," in 1887, stated that, from a study of plants in European climates, one is led to infer that foliar periodicity depends upon the alternation of seasons and therefore chiefly upon temperature and moisture, and, without wishing to deny the co-operation of these factors, he suggested that periodicity may depend chiefly upon changes which take place in the plant, independently of external influences or only indirectly affected by them. Haberlandt in his book "Botanische Tropenenreise" in 1893 draws attention to the fact that botanists are inclined, from their knowledge of European floras, to connect the periodicity of leaf-fall and foliar renewal with the periodical change of seasons in such areas, but quotes many instances which indicate that in tropical districts internal factors can be recognized. Schimper* and Ursprung† also dwell upon the tendency to interpret the phenomena in the tropics in terms of our knowledge of temperate zone plants.

It is one of the objects of this paper to prove that generalizations respecting foliar periodicities and their significance should not be made until a study of plants has been carried out in tropical areas where the physical conditions are compatible with a display of the autonomy of the plants. In temperate zones the vegetation only shows outward signs of life in spring and summer, whereas in the tropics conditions may exist for a perpetual display of activity on the part of one or more functions of the plants.

It need only be pointed out that there is not a month in the year, at Peradeniya, when all the plants are in full possession of their leaves; that some plants may produce a complete set of new leaves once or twice each year, others a complete and several sets each year, and others every month in the year, to convince anyone of the necessity of formulating plant-laws only after considering the vegetation in tropical areas.

The influence of temperature alone, suggested as being of importance by Sachs, Schimper, and many others, has been shown to be of minor importance in affecting the phenomena of leaf-fall and renewal in Ceylon. It is only in parts of the tropics where there is a minimum climatic periodicity and minimum variation in humidity and rainfall that the influence of temperature alone can be thoroughly worked out. If one attempts to work out the influence of temperature on the various functions of plants in a temperate zone he is necessarily handicapped, since he is dealing with

* Pflanzen-Geographie auf physiologischer Grundlage; Dr. Schimper, 1898.

† Anatomie und Jahresringbildung Tropischer Holzarten; Alfred Ursprung, 1900.

functions in plants, the characters and periodicities of which are to a great extent controlled by the adversities of the climate in which the plants and their ancestors have lived.

In this paper an account of observed foliar activities of known endemic and indigenous arborescent species in Ceylon, and their variation in the same or different climates is given; the adaptability of introduced species will be dealt with in a subsequent paper. Exact information of the foliar periodicities of trees in the tropics has been repeatedly asked for by Ursprung, Schimper, and others who have worked at the subject of tropical vegetation. It is only by the possession of such information that the question of internal factors in plant life in equable or tropical areas can be determined.

The investigation has also been carried out to determine how far external environment in a tropical area affects the annually recurring period of leaflessness. The information on this point has been gleaned from a study of the same species in various parts of Ceylon, Java, and countries mentioned by Ursprung.

The subject has also been studied with the view of throwing some light on the time-value of rings of growth in the stems of trees which are evergreen, partially or completely deciduous, and the general relationship of foliar periodicity to xylem differentiations in tropical or equable countries. Some palæontologists have contended that the rings of growth in the stems of fossil plants indicated the existence of a temperate-zone climate; and their absence, a more equable or tropical climate. The facts on this part of the subject will probably throw some doubt on such hypotheses.

It was generally thought that there were very few trees which pass through a leafless stage in Ceylon. In Trimen's "Flora" 16 species are described as being deciduous. The number of deciduous species herein described (excluding foreign ones) is only about ninety.

The number of species now known to be deciduous will probably be greatly increased at a later date, when the hrubby vegetation has been more closely studied. Shrubby plants are, on account of their being so small and having so few leaves, liable to be overlooked. It is only when they attain the size of a mature plant of Pavetta indica, or Brucea sumatrana that a heavy fall of leaf is likely to be noticed.

2.—Periodicity in Growth.

Though there are great differences in the periodicities of vegetative growth in all climates, they can usually be traced to external forces such as moisture, food supplies, temperature, &c., or they are the expression of apparently independent activities of the whole or parts of the plant or plants under consideration. We are here concerned with the periodicity of defoliation and the production of new leaves.

Periodicity in Temperate Zones.

In temperate zones, where seasons are pronounced, the leaves of certain trees discolour and fall during autumn and new leaf production is delayed until the warm spring time arrives. This is characteristic of trees which have thin and tender leaves. Those trees the leaves of which are tough and leathery, reduced in area, or covered with a thick cuticle may retain their leaf throughout the year. Examples of the former class are the Birch, Beech, Hawthorn, &c., and of the latter, Holly, Gorse, Conifers, &c. It is usual to regard the leafless period of these plants as one of rest, and in so far that there is a cessation, almost entirely in species with woody twigs, of the work of assimilation and the processes associated with this function, a period of relative inactivity of these functions may be acknowledged. Complete rest, however, would involve the cessation of all functional activity, and this cannot occur until the death of the plant. Schimper stated that during the winter months of temperate climates various changes may be taking place in the plants, such as conversion of starch into oil, chlorophyll into red colouring matter, production of cyanophyll in the epidermis, and the growth in length of roots, and concludes that there is no season which does not set certain functions of the plant in activity. There is however a foliar periodicity of temperate zone vegetation which is obviously directly associated with the seasons.

Periodicity in the Tropics.

In the tropics there may or may not be a climatic periodicity analogous to the seasons of temperate zones. In all tropical areas heat and light are intense, and these, together with the heavy rainfall of many places, result in a conspicuous growth of vegetation at most times of the year. Schimper stated that his observations in tropical districts, with an abundant rainfall at all seasons, convinced him that the life occurrences of the plant show a rhythmical change of periods of rest and activity.

The investigations of Sachs and Muller-Thurgau have proved that there is no such thing as a resting period for the whole of the life occurrences of the plant, but only resting periods for certain functions.

The tropical plants are just as subject to periodical changes of rest and activity as the plants of cooler zones.

Schimper asserted that where a marked climatic periodicity prevails the functions of the plants are influenced thereby, the dry seasons operating in many respects like cold ones. He contended that where the climate is nearly uniform the internal causes are chiefly or alone influential for the change of rest and activity. Such periodicity is founded on the existence of the organism and not on external conditions. Schimper believed that their connection with the latter is quite secondary and an adaptation. He also stated that the difference between such a vegetation and one subject to the influence of alternating favourable and unfavourable seasons is that in the first case the amount of rest and activity in every period or generation remains approximately the same, while in the second case it has a periodic increase and decrease.

The effect of climate on the type of vegetation is well known. The rainfall may not, in parts of Ceylon, greatly exceed that of certain portions of Great Britain, yet the scarcity or abundance of it in certain areas determines whether a desert or jungle flora shall obtain. The low-lying trees, the production of small bushes, abundance of succulent leaved plants like Suæda maritima, Salicornia species, Portulaca quadrifida, L., and others which prevail along the north-west coast of Ceylon suggest how xerophytic vegetation may become when the rainfall is below fifty inches in tropical areas.

Periodicity of Vegetation in Ceylon.

When one considers the arborescent forms in Ceylon a variety of phenomena is exhibited among the endemic and indigenous species. Schimper stated that in those parts of the tropics where there is a distinct climatic periodicity—and Peradeniya is one of these—the vegetation is influenced by this, and that plants are likely to show periods of rest and activity as in temperate zones. This is only obvious in certain species, and the phenomena observed for the different species are so complicated that they can be better studied in detail in a subsequent section.

In parts of the tropics where the rainfall is more or less evenly distributed throughout the year—as at Buitenzorg—periodicity in vegetation is still met with. Schimper believed that in districts continually supplied with abundant rain there are phases of rest and activity at all times of the year in the life-history of the plants.

In parts of the tropics like Peradeniya there is a definite climatic periodicity, and the trees may or may not show periodicities in association with this, but before describing these we will briefly summarize the conclusions which can be drawn from a study of the general vegetation in such a district.

One of the first things to impress a new arrival in Ceylon is the absence of any period during which the herbaceous and shrubby plants are all in full bloom. During the dry weather many species produce flowers in profusion, but in these cases each species seems to have a periodicity unrelated to any of those of the surrounding species and usually of very limited duration. This is best seen in plants of Bignonia Ungui, Pavetta indica, Pancratium species, Bignonia venusta, Ruellia tuberosa, and others.

On the other hand, many liliaceous plants die down in the dry weather and the bulbs burst out into new leaf immediately after the arrival of the monsoon rains. Similarly with the haulms of the giant bamboo (Dendrocalamus giganteus), which begin to elongate in June.*

Though certain herbaceous plants show a definite period of leaf or flower activity, the majority seem to be more or less productive during all times of the year, *e.g.*, Mussenda frondosa, and species of Anthurium, Clerodendron, Vinca, Panax, Allamanda, &c.

A case of unusual interest is to be seen in connection with the periodicity of species of Strobilanthes, Bl., in Ceylon, and I am indebted to Mr. Thomas Farr, Bogawantalawa, for much of the information on this subject. Trimen states that many of the species are remarkable for their gregarious occurrence in vast abundance and over large areas. The principal species form unbroken sheets of undergrowth in the forest. They usually live for several years without flowering, and though a few flowers may here and there be found every year, it is not until the plants have reached a certain age, apparently from ten to thirteen years, that the whole patch or area bursts simultaneously into blossom. These patches or districts are, according to Trimen and Farr, often of great extent, and the boundaries between those of different ages are very conspicuous, often being as distinct as if artificially sown. After this general and profuse flowering the

*Lock, R. H. : On the Growth of Giant Bamboos, with special reference to the relation between Conditions of Moisture and the Rate of Growth. Annals of the Royal Botanic Gardens, Peradeniya, Vol. II., Part II., August, 1904.

whole patch begins to wither and ripen the seed, and then dies down.

Mr. Farr informs me that there is one species, rather rare, which flowers and dies down every year, but that S. sexennis, Nees; S. pulcherrimus, And.; S. viscosus, And.; and S. calycinus, Nees, flower and die down with the most perfect regularity every twelve years.

We have therefore a periodicity which cannot be correlated with an interval of twelve months, and one which adds interest to the observations of Warming, Brandis, and others on this subject.

The arborescent vegetation is similarly striking. The fact that the trees do not all become leafless during certain months, and the irregularity in the production of new leaves and of flowers, impresses one with the great difference between the growth of vegetation in the tropics and temperate zones.

The absence of a general time agreement in floral or foliar periodicity in Ceylon vegetation at a given place is one of its striking characteristics.

Periodicity of Arborescent Plants in Ceylon.

There are about 770 endemic species in Ceylon, over 280 of which are trees. About 17 of our endemic and 78 indigenous species pass through a leafless phase at more or less regular intervals, showing that only a remarkably low proportion of Ceylon trees are deciduous. The number of deciduous introduced trees is equal to the number of deciduous indigenous and endemic trees put together, a fact which superficially considered seems to suggest that the Ceylon climate favours deciduous introduced species.

Ceylon Forest Types.

The appearance of the forest vegetation in Ceylon at various times of the year has not been described, and as many opportunities have presented themselves to the writer, an account of the forests in various parts of Ceylon— a tropical island where a definite climatic periodicity prevails—is now given.

Selecting as our first locality the forests of the Peak Wilderness, Singhe Raja, and Hinidum, where the rainfall varies from 100 to over 200 inches each year and the force of the north-east and south-west monsoons is experienced, we find that we are surrounded with some of the largest trees and most magnificent forest in the whole of the island. It is here that the species of Diospyros (ebony) reach their maximum dimensions, and where the huge trees of species of Doona, Dipterocarpus, Vatica, Garcinia, Canarium, Calophyllum, Chrysophyllum, Palaquium, and Bassia abound. I have visited these forests on many occasions and have been principally struck with the absence of any fixed period of the year when the plants undergo their change of leaf. Were it not for the occasional fall of leaf, or leafless condition of scattered trees of Dipterocarpus zeylanicus, Canarium zeylanicum, Bassia longifolia, and Trema orientalis, one might imagine that he was in the original "*Regenwälder*" so forcibly depicted by Schimper and Haberlandt. Each species seems to be acting on its own initiative, and its occupation on sloping hillsides, along river banks, or on flat areas does not appear to influence the phases of leaf-fall and production in the least. And even during the time of relative drought there is only a slight increase in the number of species which pass through their phase of defoliation, many effecting a change of leaf without ever being leafless—a phenomenon noticed by Warming in the forests of Minas-Geraes in Brazil—others remaining leafless for a few days and others for several weeks or months.

If one passes to a district where the temperature is much higher and the rainfall only 50 inches or less each year, as in the forests of the Northern Province, the same facts respecting foliar activity present themselves. In some of these forests one may meet with colossal trees of Mimusops hexandra, Chloroxylon Swietenia, Diospyros Embryopteris, Mesua ferrea, and others which, if one can forget the more oppressive atmosphere, strongly suggest the forests of wetter and cooler zones. In such dry forests one may meet with a few more species which habitually pass through a leafless stage, than in the damp districts. During the dry season from May to September, the partially or completely leafless trees of Vitex altissima, Berrya Ammonilla, Cassia fistula, Cratæva Roxburghii, and Spondias mangifera, suggest that the local vegetation is influenced more by climate than in other districts of Ceylon. But wherever one goes in Ceylon, whether along the sea coast, to the north or south of the island, on the coral islands in the Gulf of Mannar, or into the forests in the wet or arid zones, there are signs of the independence of defoliation with respect to external factors to be observed. Under the same climatic environment trees are to be seen in all stages, from the fall of the first leaf to the leafless branches and the flush of fresh green leaves, the former suggesting winter and the latter the spring time in a temperate zone. In most of the districts the leafless condition when at its maximum is always less uniform than what one is accustomed to meet with in any zone other than a tropical one.

As Holtermann* states, there are no forests in Ceylon the trees of which lose their leaves periodically for a long time; the majority are evergreen, and the manner in which the deciduous species drop their leaves varies considerably. If one confines his studies to the trees growing in or near the Botanic Garden, Peradeniya, he may be misled as to the probable character of the forest trees, as at Peradeniya there are more deciduous species introduced from other countries than in the whole of the Ceylon flora.

Frequency of Foliar Activity.

It is not so much in the number of species which become leafless as in the manner in which defoliation and foliar

* Dr. Carl Holtermann: Anatomisch-physiologische Untersuchungen in den Tropen; Berlin, 1903.

renewal are effected that the chief point of interest lies. A description has been given in another part of this paper of how the evergreen species may produce new leaf every month in the year, twice per year, or annually, and the behaviour of the deciduous species will now be described. The necessity for an annual defoliation, though obvious for many species in temperate zones, is far from apparent in tropical areas where there is no cold season analogous to a winter. In parts of the tropics where the monthly humidity and rainfall are relatively high throughout the year it is difficult to understand why the cycle of leaf-fall and renewal should coincide with that of a period of twelve months, and it would be natural to expect that the trees would become partially or completely defoliated at any time when the condition of the plant required either a change in the intensity of activity of certain functions or when the old leaves had become comparatively useless. In all parts of Ceylon, however, there is a more or less constant change of the climatic factors, and the behaviour of the plants is consequently more interesting.

The Age of the Trees when they undergo their first Leafless Stage.

This question is of the utmost importance in determining the time-value of rings of growth. It is obvious that the central cylinder of wood in the stem may be uninterrupted by rings of growth so long as the young tree continues to acquire new leaves and does not pass through a leafless phase.

Generally speaking, once a tree has passed through a normal leafless phase it becomes defoliated every succeeding year. It has also been pointed out that some trees are not defoliated until they are several years old—Bassia longifolia; and there are others which though leafless every year in their early life become more or less evergreen at a later date. This has been noticed for trees of Poinciana regia at Peradeniya and for Dalbergia Sissoo, Roxb., by Brandis. Brandis in his Forest Flora of India states (p. 149) that Dalbergia Sissoo drops its leaves from December to February, and remains leafless until April, but that though young trees are occasionally leafless for a few weeks, old trees are hardly ever without leaves.

There are some cases, in which the trees undergo defoliation and pass through a leafless stage in their first year; this has been observed with trees of Eriodendron anfractuosum, with suckers of Bombax malabaricum, and cuttings of Erythrina indica. Trees of Castilloa elastica undergo defoliation in their second year; but trees of Tectona grandis, Bassia longifolia, and Couroupita guianensis do not pass through a leafless stage in their second year. Trees of Hevea brasiliensis become defoliated in their third year, Cassia nodosa in their fourth, and Poinciana regia and Ficus religiosa in their fourth or fifth year. There are very few recorded observations available for most of our deciduous species, but in most of them it is quite possible that the leafless stage is not passed through until the trees are more than one or two years old.

The fact that defoliation during the first year of a plant's life is characteristic of quick-growing species, and that slower-growing trees do not become leafless during the first few years suggests that there may be a relative constancy between the amount of foliage and the first period of leaflessness.

The frequency of Defoliation of Trees.

I have been surprised to notice that certain trees, apparently old and vigorous, which were classed as evergreens, have during certain years (some only once during four years' observation) begun to drop their leaves and have undergone a complete renewal of foliage. Kurz* remarks that in the evergreen forests of Burma some trees lose their leaves after a certain number of years. Warming, when

* T. Kurz: Flora of British Burma, Vol. I., 1877.

describing the vegetation of the Campos of Minas-Geraes in Brazil, states that the majority of the leaves remain on the trees from twelve to fourteen months, and usually for a longer period in the forests than on the prairies. Some trees, according to Warming, retain their foliage for twenty-four months and even longer. Such cases are comparatively rare in Ceylon, but they prove that an annual defoliation is not universal with deciduous trees, and that a change of leaf at periods coinciding with our year of twelve months is not necessary for every species.

Once per year.—The majority of the observed species do not show a long or irregular interval between successive periods of defoliation. Nearly all of them pass through their leafless state once each year, and I need only mention Bombax malabaricum, Spondias mangifera, Careya arborea, Gmelina arborea, Terminalia belerica, Ficus Arnottiana, Oroxylum indicum, Bridelia retusa, Canarium zeylanicum, &c., as examples of this group.

Twice per year.—There is only one species which undergoes a change of leaf twice each year, this being Terminalia Catappa; the change of leaf in the Peradeniya district usually takes place in February to March and August to September. The tree is a native of Malaya, but is naturalized in the low-country of Ceylon, where it is known as the "kottamba" of the Sinhalese and the "country almond" of the English.

There are a few other species which are completely defoliated once a year, but which pass through the leafless stage twice during certain years. Examples may be seen in a tree of Ficus asperrima, at Peradeniya, which, though usually defoliated in March only, was defoliated in March and October in 1903. Similarly with some specimens of Couroupita guianensis.

Still another combination of foliar activity is seen in Ficus Trimeni, which appears to be subject to complete or partial defoliation in December and January, and to a partial leaf-fall in June and July of certain years. A description of the periodicity of a prominent tree of this species from 1900 to 1905 has been given in the section dealing with deciduous species indigenous to Ceylon and India. It is by no means rare to find that a particular tree which produces a complete set of new leaves after the leafless stage produces small quantities of leaves during other months of the year; such activities may be observed in trees of Swietenia Mahogani, Chloroxylon Swietenia, Terminalia belerica, Bassia longifolia, and others.

It is also not unusual to find that every alternate year the production of new leaves on certain trees is very copious, this being particularly striking in evergreen trees of Garcinia Mangosteen, Durio zibethinus, and Mangifera indica.

Abnormal Defoliation and Foliar Renewal.

In certain cases the abnormal production or fall of leaves is due to a condition of vigour, undue exposure to wind, or the attacks of animals. Trees of Acacia Suma and Canarium zeylanicum, which have lacked the vigour of other specimens of the same species, have been observed to take a much longer period to renew their foliage. The periodicities of such specimens are usually variable and unreliable.

The effect of the strong winds during certain months of the year can be observed on exposed trees of Mangifera indica, Tecoma stans, and others, these trees becoming more nearly leafless than other specimens of the same species.

I have also had an opportunity of recording the change of periodicity due to cutting away the upper parts of trees of Mangifera indica and Terminalia Catappa. A tree of Mangifera indica which normally produced its leaves in February and March was lopped in May after the full set of foliage had been established; the tree produced a large quantity of leaves during July to September of the same year, but in the following year the leaf production due in February and March was not observed. A tree of Terminalia Catappa was similarly treated in May, with the result that there was a large output of new leaves in July and August, unaccompanied by a heavy leaf-fall ; the periodicity of this tree was changed for a couple of years.

Another case of interest has been observed for several years, where the flying foxes regularly visit certain trees of Bombax malabaricum along the riverside of the Botanic Garden and devour the whole of the leaves, and thus lead to the production of two sets of foliage each year. A similar defoliation is effected on trees of Portlandia grandiflora by some insect pest and a second crop of leaves is produced each year, though the trees do not appear to be able to stand such waste for many years more.

3.—The Climate in Ceylon.

It is necessary when dealing with plant phenomena which are influenced by external and internal forces to fully understand the variation in rainfall, air-temperature, and humidity at the different places where observations have been made. Most of the facts recorded in this paper have been obtained at Peradeniya and Hakgala, a few in the low-country between Henaratgoda and Colombo, others in the dry Northern Province between Anuradhapura, Vavuniya, and Mannar, and the remainder in the Badulla and Passara Districts of the Province of Uva.

The rainfall in various parts of Ceylon is associated with definite monsoon periods, and the amount of rain accompanying each varies considerably at different places.

The south-west monsoon, according to the Government Meteorologist, usually lasts from February to July, and the north-east monsoon from August to January.

It is necessary to consider each district separately, though they all agree in having rain every month in the year, a high temperature, and an atmosphere which is comparatively moist, the average humidity rarely being below 70 degrees.

The Climate at Peradeniya.

At Peradeniya the south-west rains are heavy during April and June, and those of the north-east still heavier in

October and November. To be brief there is a warm dry period during February and March, a hotter but moister one during April and May, followed by seven to eight months of rainy weather when the temperature is comparatively low and humidity high. We can therefore speak of one hot dry and hot moist season of four months and a cooler moist period for the rest of the year. (See plates XXVI. to XXVIII.)

The Climate at Hakgala.

Hakgala is 5,581 feet above sea level. The climate resembles that at Peradeniya in having both monsoons, but differs from it in so far that (*a*) there is a heavier rainfall, mainly from October to December ; (*b*) the average yearly temperature is 15° F. lower than at Peradeniya ; and (*c*) the yearly humidity is 9 degrees higher. The periodicity of the climate is almost the same as at Peradeniya, but the air is cooler, the rainfall heavier, and the atmosphere always more moist. (See plates XXVI. to XXVIII.)

The Climate in Colombo.

Colombo is at sea level, and the climatic periodicity prevailing there is almost the same as at Peradeniya. Compared with Peradeniya the annual rainfall is nearly the same ; the temperature is on an average 5° F. higher and the air more moist. (See plates XXVI. to XXVIII.)

The Climate at Badulla.

The climate at this place is quite different from that at Peradeniya. The rains fall mainly in the north-east monsoon, and the annual rainfall is about 5 inches less than at Peradeniya. The temperature is more regular, but usually 2° F. lower than at Peradeniya. The curves show that the dry hot period is from June to September and that the rest of the year is relatively moist and cool. (See plates XXVI. to XXVIII.)

The Climate at Mannar.

The differences between the climate at Mannar and Peradeniya are obvious from the various curves, and may be summed up as follows :—The rains fall mainly in the north-east monsoon, the temperature and humidity are higher than at Peradeniya, though the annual rainfall is not half so great, and there is one dry hot season from June to September. (See plates XXVI. to XXVIII.)

We have therefore the Colombo climate at sea level, and Hakgala at over 5,000 feet, with almost the same climatic periodicities as at Peradeniya. At Mannar—sea level—and at Badulla over two thousand feet altitude, the climatic periodicities resemble each other, but differ widely from that at Peradeniya. In order to make these points still clearer I now give a tabulated synopsis taken from the Surveyor-General's report for 1902 :—

	Average Annual Rainfall. Inches.	Mean Annual Temperature. Fahrenheit.	Average Mean Annual Humidity.	Altitude in feet.
Peradeniya ...	82·16 ...	75·5 ...	78 ...	1,560
Hakgala ...	91·70 ...	60·3 ...	87 ...	5,581
Colombo ...	88·15 ...	80·7 ...	79 ...	40
Mannar ...	38·59 ...	81·8 ...	82 ...	12
Anuradhapura ...	54·20 ...	80·2 ...	78 ...	295
Jaffna ...	45·47 ...	82·0 ...	83 ...	—
Badulla ...	76·93 ...	73·2 ...	79 ...	2,225

Peradeniya and Buitenzorg.

The climate at Buitenzorg differs from that at Peradeniya in many ways. At Buitenzorg the rain during 1901 to 1904, inclusive, fell on an average of 263 days in each year. The humidity of the air in 1904 ranged from 75 in August to 85 in December, and the average for the years 1901 to 1904, inclusive, was 79. The average monthly temperature ranged in 1904 from 23·6° to 25·3° C. Though the climate in Buitenzorg is more equable than that at Peradeniya it must be borne in mind that a definite periodicity does exist, and a reference to the curves on plate XXX. will show that the rainfall and humidity throughout the year approximate to those at Badulla.

Reference has been made in another part of this paper to the marked climatic periodicity prevailing in East Java, and I am indebted to Dr. Treub for the information in the following synopsis of the monthly rainfall, humidity, and temperature at Pasœrœan in East Java and Buitenzorg.

Climate during 1904 in Java.

	Rainfall in mm.		Monthly Average mean humidity.		Monthly Average Mean Shade Temperature in °C.	
	Buitenzorg	East Java.	Buitenzorg.	East Java.	Buitenzorg.	East Java.
January ...	417	221	83	77	24·0	27·2
February ...	455	192	85	80	23·6	26·9
March ...	169	287	80	80	24·5	26·6
April ...	204	33	79	76	25·0	27·4
May ...	541	155	80	76	25·3	27·3
June ...	389	27	78	73	25·1	27·1
July ...	312	48	79	71	24·8	26·7
August ...	344	18	75	67	25·1	27·1
September ...	388	—	76	64	25·3	27·7
October ...	799	11	81	64	24·9	28·7
November ...	312	24	80	67	25·2	28·7
December ...	498	110	85	74	24·2	27·9
Average mean, yearly 1901—1904	4,416	1,200	79	71·9	25·0	27·6

4.—The Leafless Phase in the Tropics.

In studying this part of the subject we find that plants of the same species may show variation in different climates, and in the same neighbourhood, and in several cases even the same tree exhibits differences in foliar periodicities from year to year.

The facts recorded in this section lead to certain conclusions which form the stepping stones for subsequent deductions of some importance. They prove first and foremost that under tropical conditions with regular rainfall, heat, and light, and in the absence or presence of climatic periodicities certain plants undergo defoliation at a particular time of the year. They prove that in a tropical district supplied with rain during every month of the year—

Peradeniya—there is a rythmical change of periods of rest and activity. It can also be shown that the observed variability of certain species in different climates is repeated when individuals of these species are grown in the same climate or individually from year to year. It is by a consideration of such observations that one is led to infer that foliar periodicity is inherent and that in many tropical areas the internal factors are responsible for many phases of the vegetation.

On the other hand, these facts also teach us that the climatic periodicity in parts of Ceylon and Java is so marked as to influence the foliar activities. The inherent periodicity in foliar production can be affected by external climatic forces such as obtain in these places.

Variation of a Species in different Climates.

It is a matter of common knowledge that the same species grown in different climates or changed environments presents many differences. We have seen that in various parts of Ceylon different climates exist, and a discussion of the variation of plants of the same species in such localities can be conveniently introduced in this part of the paper.

The variation in foliar periodicity due to a difference of climate in Ceylon is usually one of time only, and in very few cases can it be shown that plants of the same species may be evergreen or markedly deciduous according to the climate in which they are growing. There are three species which though evergreen in the Peradeniya and wet districts in Ceylon, are partially deciduous in the dry Mannar Districts, these being Thespesia populnea, Sol.; Diospyros ovalifolia, R. Wight, and Diospyros montana, Roxb. This statement is only intended to apply to parts of Ceylon, and does not hold good when species common to Ceylon are introduced into other countries.

It will be necessary, in order to avoid confusion, to first consider the variation of a species in parts of Ceylon and then deal with the variation of indigenous species when grown in other countries.

The most conspicuous differences are met with when the foliar periodicities of plants common to Peradeniya and the Uva District are considered. In the case of Careya arborea we find that at Peradeniya the leafless stage is passed through in February or March, but at Passara in the Uva District it is usually during May and June.

Trees of Ficus Arnottiana, though passing through their stages of foliar activity at Peradeniya in March and April, show in the Passara and Lunugalla districts a production of new leaves and flowers in May and June.

Again trees of Gyrocarpus Jacquinii, though they undergo defoliation at Peradeniya during February and March, do not pass through the leafless stage until May to July in the dry parts of the Northern Province. In each case we find that defoliation occurs during the dry hot weather, and the variation in the climates already described will alone account for the change in the periodicity of these species. These examples can be used in support of the contention that the time of defoliation is associated with the external factor of climate.

Many instances can also be quoted to prove that there is considerable variation in districts which have relatively similar climatic periodicities, but which show slight differences of rainfall, temperature, and humidity. The differences in plant phenomena in such districts cannot in every case be assigned to the slight differences of climate, because we know that even in the same district the same species may exhibit considerable variation in manner and time of foliar periodicities.

Trees of Terminalia belerica usually drop their old leaves in February and March at Peradeniya, but at Ambalawa near Gampola I have seen leafless trees during the first week in January.

A still better example is seen in trees of Albizzia stipulata. In the Peradeniya district the leafless phase is during late January and early February. At Henaratgoda in 1902 the leafless period was just over with certain trees on the 12th February. At Pitakande in the Matale District, 3,000 feet above sea level, on the 20th March, one tree was leafless, one had not dropped its old leaves, but the majority were in full new leaf. In most parts of the island this species usually passes through its leafless phase during the month of February.

The most interesting case is however to be seen in Bombax malabaricum. This species is one of the most conspicuous deciduous trees in Ceylon. The frequent occurrence, huge dimensions, and long leafless period of trees of this species give the Peradeniya and low-country places quite a barren appearance from January to April each year. The period of leaf production and fall for this species shows a variation equal to a very large part of the year, and it is one instance which strongly suggests that if trees of other deciduous species were only more abundant and conspicuous the time of foliar periodicity would be proved to extend over a longer period than has been recorded for them up to the present.

Several trees have been under observation, and the following is a synopsis of records taken. The earliest dates on which leaf-fall commenced were 29th September in the Royal Botanic Garden, and on the 21st October, 1903, for a tree on the Peradeniya race-course. The majority of the trees at Peradeniya have by the 15th December each year dropped a great part of their foliage. They rapidly become leafless, and by the 15th January they are usually leafless and in flower. The flowers are produced in January and February, the fruits set in March, and disburse their seeds and cotton in April while the trees are absolutely leafless. During late April and early May the majority of the trees burst into new foliage.

Some trees were seen in flower along the Kandy road on the 12th December, 1903. On the 15th December one young tree was observed at Gangaruwa, Peradeniya, in flower before leaf-fall had commenced, a condition also noticed in the Passara district in 1902.

At Henaratgoda on 15th February, 1902, the majority of the trees had shed all leaves and flowers.

In the Gampola district on the 5th February, 1902, many trees had finished flowering and the fruits were setting.

In the Passara district, where one gets less south-west monsoon rain and where from April to August and September it is dry and hot and from September to March the rains are heavy, the trees behave differently.

Between Passara and Lunugalla at an elevation of 2,000 to 3,000 feet, on the 25th May, 1901, some of the trees were quite leafless, and others in partial new foliage ; very few had a good output of leaf on that date. In several specimens the flowers were produced long after the trees had regained complete new foliage.

Variation in Ceylon and Java.

Now we can consider the variation which occurs in climates so dissimilar as Ceylon and Java—two tropical islands near to but on opposite sides of the equator. I am indebted to Dr. Treub for much information respecting the periodicities of certain plants in Java, and the comparison obtained is interesting in many ways, particularly as details of some of the periodicities have been obtained at Buitenzorg and Peradeniya.

Peradeniya and Buitenzorg.

The best example is perhaps to be seen in trees of Bombax malabaricum. At Peradeniya the fall of old leaf is very conspicuous during December; the leafless phase extends from December to April or May, the flowers and fruits appear in January and February, and the burst of new leaf occurs in April and May. Plants of this species rarely possess any old leaf during January and very few put on new leaf before the end of April. Yet at Buitenzorg this species commences to drop its old leaves in July, five to six months after those in Ceylon.

Almost the same dissimilarity is seen in the fall of old leaf of Erythrina indica, at Peradeniya in January and February, and at Buitenzorg in July. This variation is analogous to the great differences in time between the periodicities of trees at Peradeniya and in the Province of Uva, and is all the more interesting on account of the fact that the species concerned are common in both islands.

There are several species which have been introduced to Java from Ceylon and to both islands from other countries, and the differences in their foliar periodicities are extremely interesting.

One of the most surprising examples is seen in the behaviour of Schizolobium excelsum. At Peradeniya the leaf-fall is very regular every year, but at Buitenzorg it is as irregular as it can possibly be. Dr. Treub wrote that in trees of this species, from three to ten years old, the branches of the same tree behave in different ways, some being leafless for two or three months and others at the same time having their full fresh foliage. Dr. Treub wrote that the only way to explain such remarkable differences was to assume that the climate at Buitenzorg was so equal all the year that even branches of the same tree were able to follow their own "inspiration" and thus show their autonomy.

Other equally noteworthy instances are seen in the behaviour of Hevea brasiliensis and Manihot Glaziovii, which at Buitenzorg drop their leaves during July and August, but at Peradeniya during February and March. The differences in the periodicities of other well-known species are obvious when one realizes that at Buitenzorg, Ficus religiosa, the Bo-tree, drops its leaves in March and Lagerstrœmia flos-reginæ in September.

A study of the differences of the species at these two tropical places brings forward two important facts. The first is that those species which are very dissimilar in their foliar periodicities at the two places, undergo defoliation in Ceylon during or about the only hot dry season in the year. In cases like Bombax malabaricum the leafless period coincides, very regularly, with our hot dry and part of our hot moist months, and further examples may be cited among our introduced species such as Schizolobium excelsum, Hevea brasiliensis, Manihot Glaziovii, and many others which reserve their leafless period until during the hot dry season in Ceylon. In the second place species such as Tectona grandis and Terminalia Catappa, which are irregular in foliar periodicity at Buitenzorg, are markedly deciduous during our hot dry season.

Ceylon, Buitenzorg, and East Java.

According to Ursprung the climate at Buitenzorg is relatively equable throughout the year, but in East Java there is a dry period during part of the year which gives a marked periodicity to the climate prevailing there. At Buitenzorg, in the absence of marked climatic periodicities, the development of plant life is rarely periodic, and what does occur is mainly the result of internal rather than external forces. Though such is the case, the differences in the behaviour of certain species at these two places and in Ceylon show distinctly that defoliation is considerably influenced by climatic changes.

At Buitenzorg, trees of Tectona grandis, *L.*, are never leafless at the crown, but in East Java they become absolutely leafless. In most parts of Ceylon the tree becomes quite leafless during the hot season.

Trees of Poinciana regia, Boj., are never leafless in Buitenzorg, though they pass through a leafless phase in East Java. At Peradeniya young trees become leafless, but old trees rarely pass through a leafless phase though they undergo an annual change of leaf.

I now quote a synopsis of deciduous species which show a wide variation in foliar periodicities in Ceylon and Java :—

Species.	Periodicity. Buitenzorg (Treub).	Peradeniya.
Albizzia Lebbek ...	Leaves fall in March ...	Leaves fall in December and January.
Bombax malabaricum	Leaves fall in July ...	Generally speaking, the leaves fall in December, flowers appear in January and February, fruits set and disburse their seeds in March and April, and new leaves appear April to May.
Cassia nodosa ...	Leaves fall in May and July	Leaves fall in January to March ; new leaves appear in April.
Chickrassia tabularis	Leaves fall in April ...	Leaves fall in January to February and new leaves appear in March.
Derris robusta ...	Leaves fall in March ..	Leaves fall December to March.
Dalbergia Melanoxylon	Leaves fall in March to May	Leaves fall from January to March and new leaves appear in April.
Plumeria acutifolia	Leaves fall in July to August	Usually the leaves drop during December and January.
Peltophorum ferrugineum	Leaves fall irregularly ; July (1898) ; March, 1899	Leaves fall irregularly during December to January and June to July.
Schizolobium excelsum	Leaves fall very irregularly	Very regular. Leaves fall from the end of January throughout February, and by the 10th March the tree is leafless ; is in flower and new leaf by 15th March.
Schleichera trijuga	Leaves fall in April ...	Leaves fall during February and March on tree in open, and irregularly on a tree under partial shade.
Sapium biglandulosum	Leaves fall in April ...	Leaves fall from February to April.

Species.	Periodicity. Buitenzorg (Treub).	Periodicity. Peradeniya.
Terminalia Catappa	Leaves fall very irregularly, often twice a year	Undergoes defoliation and foliar renewal regularly twice per year, first from January to February, and second from August to September (1900 to 1904).
Tectona grandis ...	Almost evergreen ...	Markedly deciduous. Leaves fall from January to March and the tree is perfectly leafless for about one week.
Erythrina indica ...	Leaves fall in July ...	Leaves fall in January and February and new leaves appear in March and April.
Ficus religiosa ...	Leaves fall in March ...	Variable, but the leaves usually fall from December to March.
Ficus infectoria ...	Leaves fall in March and April	Leaves fall during February and March.
Ficus elastica ...	Leaves fall in April, new leaves appear in April	Irregular; leaves fall from September to February.
Ficus altissima ...	Leaves fall in March ...	Irregular. Leaves fall during the dry weather from February to May.
Hevea brasiliensis...	Leaves fall in July ...	The leaves usually fall in February, some a little earlier, and others later. Nearly every tree is in full new leaf in March.
Lagerstrœmia flos-reginæ	Leaves fall in September	Leaves usually fall in January to February and in March new leaves appear.
Manihot Glaziovii...	Leaves fall in August...	Leaves usually fall during February and March and new leaves appear in April and May.
Pithecolobium Saman	Leaves fall in February, March, and July	Variable. Usually old leaves fall in January and February and new leaves appear in February and March.

To further prove the effect of external forces on foliar periodicity I need only draw up a tabulated list showing the behaviour of species quoted by Ursprung for various parts of the world and the same species at Peradeniya :—

Species.	Ursprung.	Peradeniya.
Ficus infectoria ...	India. Throws off large quantity of leaf	Markedly deciduous.
Ficus glomerata ...	India. Evergreen ...	Deciduous.
Ficus elastica ...	Evergreen ...	Partially deciduous.
Anona reticulata, Mart.	Leafless in dry season ...	Evergreen.
Persea gratissima, Gaer.	In tropical America, evergreen with two conspicuous periods of leaf production. In Mexico, evergreen with development of young leaves in September. In Mexico there is no rain from October to April, plenty of rain May to September	Evergreen with one period of active leaf production in April.
Thespesia populnea, Corr.	East Indies. Evergreen...	Evergreen. Partially deciduous in Gulf of Mannar.
Erythrina velutina, Willd.	In Venezuela, leafless during September and October	Leafless January to March.

Variation of Individuals of a Species in the same Climate.

A glance at the tabulated periodicities will convince anyone of the great individual variation, particularly in specimens of Bridelia retusa, Careya arborea, Ficus Arnottiana, Lagerstrœmia flos-reginæ, Bombax malabaricum, Oroxylum indicum, Berrya Ammonilla, and many others.

The differences between the periodicities of several trees of Lagerstrœmia flos-reginæ are shown in the tabulated list. Generally speaking, defoliation at Peradeniya is conspicuous during January and February, and in March new leaves appear. Nevertheless on any date during the months of March and April it is possible to find trees which show every stage from the discoloured leaves ready to fall to the trees in full new leaf and flower.

Individual trees of Eriodendron anfractuosum show at Peradeniya a production of new leaves during the months of December, January, and February.

Bridelia retusa is also very variable. In the Peradeniya and Henaratgoda districts the fall of leaf is most conspicuous during the months of February and March, but many trees of this species undergo defoliation during April and May, and in these cases the production of new foliage is correspondingly delayed. During February to April, trees in the Peradeniya district may be seen dropping their old leaves, absolutely leafless or in full new leaf.

Again Terminalia belerica, though it usually behaves as quoted in the list, is subject to some variation. The majority of the trees at Peradeniya have shed all their leaves by the end of February, and are in full new leaf before the end of March. One tree under observation does not drop its leaves until a much later part of the year, becoming leafless from the 1st to 7th April each year. Others have been recorded which do not produce new leaf until the middle of May, and some have been observed to shed their leaves, in part, during November, December, and January.

It is only logical to expect much variation between individuals of the same species in the same climate, seeing that even the same tree may show a variation from year to year.

Variation of the same Tree, in successive Years, in time of Foliar Activity.

The same tree may undergo depletion and renewal of foliage at approximately the same time during each year. But there are others which are variable. The periodicities described for each individual tree of the species common to India and Ceylon show that several may exhibit a slight inconstancy from year to year, a phenomenon also to be observed for species belonging to other countries. The species of particular note are Anogeissus latifolia, Bridelia retusa, Careya arborea, and Ficus Tsjakela.

One tree of Anogeissus latifolia was leafless during 1902 from the 10th to 12th March ; in 1903 from 24th March to 6th April, and in 1904 the tree was never absolutely leafless.

A tree of Bridelia retusa was leafless during 1902 from the 12th to 24th March, and in 1903 from 24th March to 7th April.

Similarly a specimen of Careya arborea was leafless during 1902 from 15th February to 15th March ; from 12th to 24th March, 1903 ; and in 1904 from 7th February to 8th March.

Again, a tree of Ficus Tsjakela was leafless from 12th to 20th February in 1902 ; from 6th February to 1st March, 1903 ; and from 18th February to 16th March in 1904.

In three out of four cases the leafless period was delayed in 1903, compared with 1902 ; in one case for 1904 the periodicity was delayed, and in another defoliation was earlier in 1904 than in 1902 and 1903.

Similar differences have been noticed for individual trees of other species, as for instance Gmelina arborea and Berrya Ammonilla, common to Ceylon, India, and the Malay Archipelago.

The date at which leaf-fall commences is very variable and is not of much importance. The actual length of time during which the tree is leafless is of much more importance.

The variation in time, of the foliar periodicities of species like Spondias mangifera, Bombax malabaricum, Eriodendron anfractuosum, Bridelia retusa, or Lagerstrœmia flos-reginæ, is usually greater than the variation exhibited by an individual tree during successive years. For instance, the foliar periodicity of different trees of Bombax malabaricum may in the same district vary by one or two months in the same year, but an individual tree during 1900 to 1905 does not vary in its periods of leaf activity by more than a few days or a few weeks at the most. In many of the cases under observation the trees were nearly all of the same size and age, and the difference in their periodicities during a given year points to the importance of the individual requirements of each tree and the relative insignificance of external or climatic forces in connection with foliar periodicity.

5.—Transpiration in Ceylon and the Tropics generally.

The production of new leaves is closely associated with root activity and the transpiration of water from the leaves. The phenomenon of defoliation at regular intervals is similarly related, and for a proper understanding of foliar periodicity in Ceylon and the tropics generally it is necessary to consider the subject of transpiration in such regions. In temperate zones the deciduous trees lose most water by transpiration from the young spring leaves, or during the summer months when the full complement of foliage is exposed to a relatively hot and dry atmosphere; in autumn the loss by transpiration is reduced, and during winter the trees are leafless.

From the foregoing remarks it is obvious that in tropical areas there is no period exactly analogous to a temperate zone winter. In many parts of the tropics the conditions allow of transpiration throughout the greater part of the year, and in other areas short periods of dry weather may intervene. The available literature dealing with this aspect of the subject is somewhat scanty, and the following remarks are mainly in reference to observations made in Ceylon.

The transpiration of plants is influenced by the temperature and humidity of the air. In the tropics the temperature is usually high and the humidity high or low. Where the temperature and humidity are uniformly high, the vegetation is rarely xerophytic, as is evidenced in parts of Ceylon and Buitenzorg in Java. If however the temperature is high and the rainfall meagre, the plants become spiny or succulent and the xerophytic type of vegetation may predominate;

this is seen in the flora of the Iranativu islands in the Gulf of Mannar. When the temperature is high and the air saturated with moisture, as in the hilly districts in the south of Ceylon, the vegetation is abundant and succulent types frequently occur. Roughly speaking, as one passes from an area where the humidity is medium to one where the air is very dry, or where it is very moist, the plant adaptations against excessive transpiration are on the increase. The adaptations are such that the trees transpire partially or wholly by means of their stems, and the leaves become more or less negligible in the function of transpiration; in other cases the leaves may reduce their stomata in number and size and increase the water capacity of the internal tissues. In the other class of plants about to be considered the adaptations to transpiration are seen in the partial or complete defoliation of the trees and the output of new leaves at various periods, and in order to understand this it is necessary to first discuss the question as to the relative amount of water lost by transpiration in temperate and tropical zones, a point which has been the subject of much experiment.

Giltay states, according to Schimper, that the daily transpiration in plants of Helianthus tuberosus grown at Buitenzorg and Holland is approximately the same, viz., 0·6 gram per hour, though transpiration at midday, at the former place, is considerably greater than that in the latter. Haberlandt made determinations of the relative amounts of moisture lost from the leaves of trees like Albizzia moluccana and Theobroma Cacao, at Buitenzorg, and Pyrus communis, &c., at Graz. His experiments proved that the transpiration in shade, in moist tropical climates, is much weaker than in middle Europe.

Haberlandt's results have been criticised by Burgerstein* and others, who point out that the conclusions can only be applied to a few plants under the conditions described by

* Burgerstein, A.; Die Transpiration der Pflanzen; Jena, 1904, p. 161.

Haberlandt, and that it would not be fair to assume that the loss by transpiration would be so small from forest and other trees exposed to tropical conditions.

Wiesner* worked with herbaceous plants such as Coleus, Adiantum, Jatropa, and Mimosa pudica and proved that these plants, at Buitenzorg, lost very large quantities of water during hot cloudless days.

Wiesner also proved that in the temperate zones the early deciduous species may lose a greater quantity of water than those which drop their leaves later in the year, and in some cases even more than those which are evergreen.

Transpiration in Ceylon.

Holtermann, who worked in various parts of Ceylon, has published some interesting results bearing on this subject. Describing the humidity of the air at Peradeniya, he points out that on ordinary days with a clear sky, in the dry season, evaporation commences after sunrise and remains feeble up to 10 A.M., but from this time it increases until between twelve and three it reaches its maximum, and then decreases until sunset, and subsequently dew is formed. Transpiration stops nearly or completely after sunset, when saturation point is being approached. The stomata are usually closed during the night.

At Peradeniya, from January to March there is a dry wind, and during this period transpiration is greater, and may even continue all through the night. The evaporation on moist days, when the air is saturated, is very slight or scarcely perceptible. In order to emphasize the great difference between the transpiration during hot dry and wet days he states that Asplenium Nidus during misty days lost from 0·00 to 0·21 gram of water per day, but on a sunny day it transpired as much as 3·50 grams.

Holtermann worked with various plants. Cymbidium bicolor—a common epiphytic orchid—was selected among

* Wiesner, Julius : Über Laubfall infolge Sinkens des absoluten Lichtgenusses (Sommerlaubfall) ; Botan. Gesel., Berlin, 1904.

others. This plant possesses thick stiff leaves (which are protected by a strong thick cuticle and a layer of cells running under the epidermis on the upper surface of the leaf) and narrow stomata. He proved that the transpiration from one plant of this species was, from the 23rd to the 27th January, both days inclusive, only 0·457 gram, or at the rate of about one gram in ten days. This means approximately one pound of water in 13 years, a very small quantity indeed.

Alstonia scholaris was also experimented with. The leaves of this commonly occurring tree are not xerophytic; they possess normal stomata and internal tissues, and a cuticle of average thickness. One shrub of this plant possessing 100 leaves lost during the 13th and 14th February, when the sky was cloudless and the temperature high, 1·24 gram; but during the 15th and 16th when rain was falling only 0·06 gram of moisture was lost by transpiration. Discussing the value of these and other observations Holtermann proceeds to state that there is between 12 and 2 o'clock on clear days in the tropics a much greater loss of water by transpiration than in Europe, though the total transpiration of a tropical plant in 24 hours may be less than in Europe.

There are in the tropics a large number of plants which though exposed to the full rays of the sun only lose a small quantity of moisture by transpiration; *e.g.*, Euphorbia antiquorum, Cereus triquetra, and others. The leaves of these plants are small, and the green stems often carry on the greater part of the work of transpiration and assimilation. The stems of such plants are provided with a thick epidermis and deeply sunk stomata. On a very hot day in a very exposed place Cereus triquetra lost, according to Holtermann, from 8 A.M. to 6 P.M., only 0·01 gram per square decimeter.

Holtermann also carried out experiments which proved that the tobacco plant lost twice as much moisture at Jaffna as at Peradeniya, and that *the transpiration in the drier districts of north Ceylon is considerably greater than in the moist climate in the south-west of the island.* He also states that though a change of external conditions did not lead to any great difference in the transpiration from Cyanotis zeylanica, yet other plants which had been transplanted into pots transpired more than those cultivated under natural conditions, and showed striking changes in the anatomy of their roots. He also states that the transpiration in moist tropical climates is less significant than that from quick-growing plants in the warm and sunny part of an European climate. On the other hand at certain hours of a clear sunny day in the tropics the transpiration is undoubtedly much greater than in Europe. He also points out that transpiration in the dry districts of the Northern Province is much greater than in the moist warm climate of Peradeniya.

The actual weight of water lost by large tropical trees cannot be determined with ease, and it would not be safe to estimate the probable amount from the results of experiments with branches and seedlings of particular species. Certainly the amount of water lost from branches of trees can be determined, and more or less approximate calculations made of the amount likely to be lost by the whole of the tree, but the absence of a proper system of roots on such cuttings prevents one from using the results with an assurance of their general applicability. The experiments do, however, suggest that in many of the ordinary arborescent forms growing in the tropics, the transpiration is not necessarily greater than in Europe. In all probability the transpiration from certain trees at Peradeniya in the moist dull months of June and July is less vigorous than in Europe during summer—certainly the assimilation processes in the leaves are almost at a standstill at Peradeniya during that time. The transpiration throughout the year at Buitenzorg, and at Peradeniya from May to December, is apparently not much more vigorous than in middle Europe in summer. There is therefore no reason to expect that special structures should be formed in tropical plants to meet the exigencies of transpiration during the months mentioned, and the possession of abundance of foliage in both areas during such periods is what one may logically expect to find. But the climate is not always so moist and dull, and during the remaining part of the year certain changes may occur. At Buitenzorg, with a relatively equable climate and transpiration throughout the year, the trees are more or less evergreen, and foliar periodicity is mainly determined by internal forces.

In a tropical district like Peradeniya, where a marked dry season sets in, a large number of trees drop their leaves during the hot dry season between January and March, probably because they find it impossible to obtain the amount of water in the soil equal to that which would be lost by transpiration if they retained the full complement of foliage. Certain forms retain their full amount of foliage, and others are provided with adaptations which allow them to pass through a period of drought unimpaired.

In a temperate zone the roots cannot absorb the required amount of water during the cold months, and the trees therefore drop their leaves for the winter and remain in that state until the warm spring weather arrives.

We are therefore led to conclude that foliar periodicity is associated with transpiration, and that the latter varies according to the temperature and moisture of the air and soil. It remains to be shown how far the results of the observations made in Ceylon agree with these conclusions, and the questions connected therewith can now be considered.

Periodicity and Transpiration.

From the foregoing considerations several interesting questions arise. The first is a question as to the extent of the reduction in transpiration which is effected by species passing through their leafless phase during the hot period in Ceylon.

That defoliation in deciduous trees is associated with the hottest and driest period, and therefore probably with reduction of transpiration, seems obvious from the facts: (1) that a large percentage of our endemic and indigenous species are deciduous during this dry hot period ; and (2) that the greater number of our introduced species obtained from such widely different climates as Brazil, Java, Australia, America, Africa, West Indies, &c., undergo defoliation from January to March. These facts suggest that reduction of transpiration is perhaps one of the objects in view. During these months when the air is usually dry and the temperature high, the leaves of many evergreen plants begin to flag during midday and only expand in the late evening and early morning. Throughout this period the leaves transpire copiously and probably thus allow the greater part of the water supplied by the roots to escape. The temperature, two feet below the ground, rises to 83° F., and during this period the water supply to the superficial root system is somewhat limited. Under these conditions one can see the advantage of, and in certain cases almost the necessity for, a reduction in transpiration such as may be achieved by passing through a leafless phase. The actual variation in temperature—one to two feet below ground—is not very great, but the maximum during certain months is high, and the water supply to the feeding rootlets at two feet below ground must be appreciably affected.

The following are the temperatures in Fahrenheit from January to May, 1903, recorded at the Experiment Station, Peradeniya :—

	Jan.	Feb.	March.	April.	May.
One foot below ground ...	73 to 78 ...	73 to 78 ...	76 to 81 ...	79 to 83 ...	76 to 83
Two feet below ground ...	74 to 79 ...	75 to 78 ...	77 to 80 ...	80 to 82 ...	78 to 82

Having shown that the leafless phase is associated with our dry hot period and that the conditions of air and soil are such as to necessitate a reduction in transpiration during the drought, the question of the unanimity between the foliar activities of the different species during this period can be studied.

If the reduction in transpiration is really of vital importance or even an appreciable advantage to the plant, one would expect to find some semblance to order and regularity, particularly in the period during which the plants are leafless and the time of production of young tender foliage.

Holtermann proved that transpiration was greater from young leaves than from old ones, and greater during the hot dry period at Peradeniya than during other parts of the year. Yet there are many trees, *e.g.*, Albizzia procera, with tender thin foliage which retain all their leaves during the period when transpiration is at the maximum ; and, on the other hand, trees such as species of Ficus, with tough leathery leaves coated with a thick cuticle and therefore probably losing less by transpiration, become leafless. If, however, species such as Bombax malabaricum or Cratæva Roxburghii be considered, the reduction in transpiration will be found to be very great. The Bombax trees remain leafless for 32 to 96 days during our hottest and driest period, and usually produce new leaf at the end of the drought. One tree of Cratæva Roxburghii has been observed to be leafless for 31 to 76 days each year, and this specimen never regains full foliage until March or April. But when species such as Phyllanthus indicus, Careya arborea, Ficus Tsjakela, Sterculia Balanghas, Terminalia belerica, Chickrassia tabularis, and many others are studied it is seen that though they become leafless during the hot months for one or two days or weeks, they always produce their complete outfit of new tender foliage while the hot dry season is prevailing.

For these reasons one must assume that checking transpiration is only a consideration to certain species, and that others may, by passing through their foliar stages like those last mentioned, actually lead to *an increase in transpiration at a time when the minimum quantity of water is available in the soil.*

6.—The relative importance of the physical factors: temperature, humidity, rainfall, and light.

It has been shown that the climatic changes at Peradeniya are coincident with periodical foliar phenomena, and that when the atmospheric humidity is low and the rainfall scanty, there is a large increase in the number of trees which drop their leaves and remain leafless for varying periods of time.

It is now necessary to deal analytically with the separate factors, and if possible to determine the relative significance of a variation of temperature, humidity, rainfall, and light on the foliar periodicities of plants in Ceylon. The factors, when acting together in different intensities, have been shown to produce an effect on the *time* of defoliation, in the section dealing with the influence of climate. The power of each factor can be considered in regard to the effect on the manner and time of defoliation and also on the *number* of deciduous species.

Temperature.

The high temperature in the tropics so forcibly impresses the ordinary visitor that he naturally expects that its influence on plant growth and therefore foliar periodicity will be considerable. Sachs, when speaking of vegetative activity and rest, suggested that the periodicity may chiefly depend upon *temperature* and moisture. He stated that in any one species, each vegetative phenomenon possessed its cardinal points of temperature, and when dealing with deciduous trees in temperate zones he asserted that it was mainly the lower temperature of winter which led to defoliation, and the rise in temperature in spring which made it possible for the shoots to burst into new leaf.

Vines states that for any given degree of temperature there is a corresponding rate of growth.

Pfeffer points out that in certain cases the growth of leaves is unaffected by variations of temperature.

Schimper, after describing the high temperature and luxuriant vegetation in the tropics, stated that the importance of temperature as a factor influencing the development of tropical forests is less significant than that of the hygrometric conditions of the air.

In this part of the paper we are concerned with the possible effect of a high temperature or variation of temperature on the fall of old leaves and the production of new ones.

To determine the effect of a difference in temperature alone it would be necessary to select districts where the rainfall, humidity, and climatic periodicities were the same—an agreement which it is impossible to find in any part of Ceylon.

Colombo and Hakgala are approximately similar to Peradeniya as regards annual rainfall and climatic periodicity, but the humidity at Hakgala is much higher than at either place, and our comparison is therefore confined to Colombo and Peradeniya. At Colombo the humidity is one degree higher and the rainfall about six inches greater than at Peradeniya. The temperature is 5° F. higher at Colombo than at Peradeniya. The higher temperature in the Colombo district is not accompanied by a notable increase in the number of deciduous species. The differences in temperature alone in parts of Ceylon appear to have very little, if any, effect on the phenomenon of defoliation. It is true that at Hakgala and other places at high altitudes the temperature is 15° F. lower than at Peradeniya, and the vegetation is almost evergreen; but it is equally true that at Mannar with a temperature more than 6° F. higher than at Peradeniya there is not a proportionate increase in the number of deciduous species. A slight increase in the deciduous species may be met with in the inland hot northern parts of Ceylon, but it can usually be ascribed more to the poor rainfall and low humidity rather than to the high temperature. Disregarding differences of climate, there occurs in Ceylon a decrease in the number of deciduous species with a fall in temperature, and equality or slight increase with a rise of temperature. In passing from the tropics to the temperate zones there is an increase in the percentage number of deciduous trees with a decrease in temperature.

The general facts may be summarized as follows :—

(1) A high temperature in the tropics compared to Europe is not necessarily accompanied by an increase in the percentage number of deciduous arborescent species (*cf.* Colombo and England).

(2) A decrease in temperature accompanied by a marked climatic periodicity is associated with an increase in the percentage number of deciduous species, if the tree flora of Great Britain is compared with that of Ceylon.

(3) A decrease in temperature in parts of Ceylon where the climatic periodicity is nearly the same does not lead to an increase in the number of deciduous species (*cf.* Hakgala and Peradeniya).

(4) An increase in temperature in other parts of the same tropical island is not necessarily accompanied by a proportionate increase in the number of deciduous species (*cf.* Colombo, Mannar, and Peradeniya). This appears to contradict (3).

(5) An increase or decrease in temperature in the same district (Peradeniya) is not concomitant with an increase or decrease in the number of deciduous species. At Peradeniya the temperature gradually rises from February to May, and the number of deciduous species first increases and then steadily declines. In May the temperature is at the maximum and is on an average 3·6° F. higher than in February, but the number of species which are either leafless or undergoing defoliation in May is five times *less* than in February. If the temperature and number of deciduous species throughout each month of the year be considered, it will be seen that from January to March there is a rise in temperature and an increase in deciduous species, a further rise in temperature from March to May with a decrease in the deciduous species, a fall in temperature and a decrease in the number of deciduous species from June to January. (See plate XXVI.)

These facts seem to suggest that in parts of Ceylon, and probably in the tropics generally, the effect of a high temperature alone, or the variation in temperature on defoliation, is of minimum importance, and in comparison to the power of other factors may be almost neglected. It would be much more difficult and perhaps impossible to determine the effect of temperature on defoliation in Europe, where the great differences in seasonal climate are so powerful and all important.

Of the three factors, temperature, humidity of the air, and rainfall, the variation in temperature is probably of least importance in determining whether a tree shall or shall not be deciduous.

Moisture.

The effect of changes of moisture on vegetative growth has been worked out for many plants in the temperate zones and for a few species in the tropics.

Reinke worked with species of Helianthus, Datura, and others ; Baranetzky and Godlewski with Brassica, Phaseolus, &c.; Darwin with Cucurbita and Kraus, and Lock with tropical bamboos.

In most cases a relationship between the rate of growth of various parts of plants and the hygrometric state of the atmosphere was established, and in the results of Lock one is struck with the remarkable dependence of the rate of growth on the changes in the humidity of the air. The relationship between the production of new leaf on the tropical trees here considered and the change in hygrometric conditions is equally striking, and furnishes another proof of the great importance of this factor in the growth of leaves in the tropics.

(*a*) *Rainfall.*

In a district like Peradeniya there is a coincidence between the period of drought and the number of deciduous species, the minimum monthly rainfall and the maximum number of species undergoing defoliation being in February and March. During August and September there is a marked decline in the monthly rainfall, but only one or two species are conspicuous in their leaf-fall during that period, the rains preceding and following this miniature drought apparently being such as to obviate the necessity for a more general leafless condition.

At Hakgala, though there is a drought during February and March very similar in intensity to that at Peradeniya, yet the vegetation is by no means strikingly deciduous, and if it were not for the few leafless trees of Meliosma Arnottiana, the introduced fruit trees, and species of Cedrela, Michelia, &c., it might be described as typically evergreen. Nevertheless there is a response to the period of drought in so far that a large number of the deciduous trees pass through their leafless phase at that time.

Similarly it can be shown that in parts of the Uva and Northern Provinces the periods of drought, though occurring at widely different times of the year compared with Peradeniya and Hakgala, are coincident with the fall of leaf from a large number of trees. But in all these cases it should not be forgotten that the minimum monthly rainfall is coincident with the minimum monthly humidity of the air—a point which suggests that either factor may be equally potent in leading to the production of a temporary deciduous character in the vegetation.

In comparing various districts in Ceylon which are widely different from Peradeniya in their annual rainfall, say Hakgala with 91·7 inches, Badulla with 76·93, and Mannar with 38·59 inches, it will be noticed that the annual quantity of rainfall is not arithmetically related to the number of deciduous species in each district. For instance, Hakgala with a heavier rainfall shows less deciduous species than Peradeniya, but Badulla and Mannar, though they have less rainfall than Peradeniya, do not necessarily show a larger number of deciduous species, and it is therefore necessary to consider the united influence of humidity of the air and rainfall.

(*b*) *Atmospheric Humidity.*

The humidity of the air is probably one of the most important factors in the defoliation of trees in the tropics.

It can be shown by comparing Peradeniya, Hakgala, Colombo, Badulla, and Mannar, that the maximum yearly humidity obtains at Hakgala where the vegetation is more nearly evergreen than at any of the other places, and that the minimum humidity is at Peradeniya where the vegetation is perhaps more deciduous than in any of the places mentioned. The high humidity at Mannar—four degrees higher than at Peradeniya—is probably responsible for the stunted and often succulent nature of the vegetation and for the non-increase in the number of deciduous species compared with Peradeniya.

It is important to notice that the Peradeniya, Hakgala, Colombo, and Badulla districts, which represent different climates, ranging from sea level, to over five thousand feet above sea level show a definite relationship between a particular stage of humidity and defoliation. In all these districts it is only when the humidity falls *near to or below 70 degrees* that the majority of the deciduous species drop their leaves.

The best agreement is, however, between the varying humidity and number of deciduous trees at a given place, throughout the year. In each of the districts mentioned the number of deciduous species increases with increased dryness of the air and decreases with an increase in the dampness of the air. If the curves showing the relationship between humidity and number of deciduous species at Peradeniya are examined it will be seen that the minimum humidity is experienced in February and March, and these are the months when the maximum percentage number of deciduous species drop their leaves or become leafless. In April and May, when the temperature is higher, the number of leafless trees does not increase, but actually decreases on account of an increase in the dampness or humidity of the air. During the rest of the year when the air is very damp the number of deciduous species which become leafless is very small, and when the maximum humidity obtains from June to October the number of leafless species is at the minimum.

The main points may therefore be briefly summarized in order to see which factor or factors are most instrumental in the phenomena under consideration.

In the following table the monthly humidity, temperature, and rainfall at Peradeniya are given, and also a column showing the number of species which are either leafless or passing through some stage of defoliation during each month in the same district (*cf.* plate XXIX.).

Month.	Rainfall in Inches.	Mean Monthly Humidity.	Mean Monthly Temperature, Fahrenheit.	Number of Species, Leafless or undergoing Defoliation.
January	4·75	77	73·2	37
February	2·37	71	75·0	47
March	3·48	71	77·3	45
April	7·59	77	77·5	24
May	5·95	78	78·6	10
June	9·11	81	75·5	5
July	6·85	81	74·9	3
August	5·74	81	74·9	3
September	5·69	80	74·9	2
October	10·99	82	75·2	5
November	10·69	79	75·3	9
December	8·95	81	73·4	24

It is in the combined effect of rainfall and atmospheric humidity that one can discern the principal agent in connection with foliar phenomena, in various parts of the tropics. The relative humidity of the air can be correlated with the amount of moisture lost by transpiration, and on the rainfall depends the supply of water to make good that lost by the leaves. Both factors are therefore of great importance in connection with leaf-fall and foliar renewal. At a given place the increase in atmospheric humidity usually follows or accompanies that of the rainfall, and during a period of drought the humidity is correspondingly reduced.

A glance at the curve indicating the number of species which are leafless or undergoing defoliation during each month shows that in February when the rainfall and humidity are at the minimum the defoliation of the species is most active, and the same conclusion holds good for the dry month of March. But in April the rainfall and humidity of the air increase considerably, and though the temperature is higher than in February or March, the number of trees undergoing their leaf change is considerably reduced. Equally striking is the fact that from June to October the humidity is near the maximum, the rainfall is abundant, and the defoliation of the deciduous trees is at the minimum. A better or more complete comparison could not be desired to prove that in a climate like that at Peradeniya there is an increase in the defoliation or leafless stage of deciduous species during the dry period and a decrease during the hot moist or relatively cool and moist periods.

In other parts of the island such as Nuwara Eliya and Hakgala there is a coincidence between high humidity and heavy rainfall and the prevalence of a more or less evergreen vegetation. At Mannar a low rainfall and high atmospheric humidity prevail, and there is an approximate similarity in the number of deciduous species to that at Peradeniya. Such facts indicate the importance of humidity in connection with defoliation in the tropics.

From considerations of the humidity, rainfall, temperature, and foliar periodicity in Buitenzorg, East Java, and parts of Ceylon, it may be concluded that (1) a high temperature is of the minimum importance, and (2) low humidity and scanty rainfall are clearly associated with leaf-fall. Where the humidity and rainfall are more or less constant throughout the year there is less agreement between the time of foliar activities ; where there is a wide variation in these factors throughout the year there is a more marked leaf-fall at the driest time of the year.

The effect of Light.

Wiesner worked with several plants in Europe and showed that transpiration decreased with a diminution in the intensity of light, and that the reduction of the latter as autumn advanced exercised an indirect influence on the leaf-fall.

It has often been observed that the completeness of defoliation of individual trees belonging to the same species at Peradeniya is variable, and in most cases this variability can be associated with the conditions of canopy under which the trees are growing. When dealing with the deciduous species indigenous to Ceylon, India, and Java, the periodicities of two trees (A) and (B) of Schleichera trijuga will be given. The two trees of this species growing at Peradeniya are differently situated and behave differently in their foliar periodicity.

Tree A is on open ground and receives light from all directions. The trees around it do not rob it of much light.

Tree B only receives the midday sun and is well protected from excessive light in the morning and afternoon. In behaviour it differs from tree A in that the defoliation is less simultaneous over all parts of the tree and the active foliar period is of much longer duration. These differences may be due to the conditions of canopy under which the trees live.

Many trees of Lagerstrœmia flos-reginæ, grown in the open, drop their old leaves more or less simultaneously over all parts of the tree and remain absolutely leafless for one or more weeks; other trees drop their leaves gradually and put on a few new leaves before the old ones have fallen. Trees belonging to the latter class take a longer period of time to effect complete renewal of foliage, and are usually growing under conditions of partial shade.

The same remarks apply to trees of Bridelia retusa, Ficus religiosa, and a few introduced species. In all cases the existence of dense shade seems to prolong the period of defoliation, and in some cases may prevent simultaneous leaf-fall from taking place.

This is an important point to notice, as it suggests that the difference between a conspicuously deciduous tree and one which undergoes partial defoliation at intervals may be due to the difference in the extent of exposure to light and wind. It certainly shows that by a slight change in the external environment the completeness and duration of defoliation is considerably altered.

Another point of some importance is the direction of defoliation, which in most cases is probably influenced by exposure to light. Trees of Berrya Ammonilla, Spondias mangifera, and Bertholletia excelsa, growing on open ground at Peradeniya are invariably defoliated from above downwards.

Trees of Ficus altissima, F. bengalensis, and Lecythis Pohlii, growing under unequal shade are, on the other hand, defoliated first on one side only. The order of appearance of new leaf usually follows the same sequence as the fall of the old, the twigs which are first leafless receiving the first set of new leaves independent of their age.

7.—External and internal Factors.

Haberlandt, when discussing the question of internal forces, stated that in those tropical districts where there is abundant moisture throughout the year and where the evergreen "rain forests" are seen at their best, periodicity in leaf production is not to be observed, the trees throwing off their old leaves and developing new ones the whole year round. In such cases foliar phenomena can only have their origin in forces other that those of climate. He also points out, however, that in those districts of the tropical zone where there is a rainy season and a dry one the winter of the temperate zones is represented by the latter.

Sachs, when dealing with the periodic alternation of vegetative activity and rest, stated that this matter must depend chiefly upon changes which take place in the resting plant, independently of external influences, or only indirectly affected by them.

It remains to be shown how different species in Ceylon give evidence of their independence or dependence on external conditions.

Internal Factors.

The fact that very few species pass through a leafless period each year, and that many evergreens produce new leaf at all times of the year suggests that foliar periodicity is largely a question of the individual convenience of the plants and is influenced only slightly by the climatic environment. The differences in climatic conditions throughout the year at Peradeniya are apparently not such as to afford any great advantage to change of leaf during a specified period, and the majority of the plants therefore produce new leaf at the initiative of internal requirements.

Out of a total number of 650 endemic and indigenous arborescent species, no less than 560 are evergreen, and the foliar periodicity of the evergreens is as irregular as it can be. There is not a month in the year when some of the species are not producing new leaf or shedding the old. The foliar renewal of the evergreens may take place annually, as in Mesua ferrea, bi-annually as with species of Diospyros, or monthly as with species of Cinnamomum. Even species which produce very large quantities of new leaves at a particular time of the year are subject to periods of minor foliar activity during the rest of the year. The individual branches produce leaves at irregular intervals, apparently without any concord with the rest of the tree of which they form a part.

The second fact of significance is that the deciduous endemic and indigenous trees do not select the same time of the year for shedding their old leaves or for foliar repletion, and there is not a month in the year when the deciduous species are all in full leaf. This irregularity obtains though all the plants may be growing under the same climatic conditions. The curves on plate XXIX. show that one or more species may be defoliated during every month in the year.

In the third place it is of interest to note that plants of the same species, *e.g.*, Cassia Fistula, may undergo defoliation and foliar renewal at approximately the same time of the year, though growing in the dissimilar climates of Peradeniya, Colombo, Vavuniya, and Mannar; this suggests that the foliar periodicity is inherent and will make itself evident even under a variety of exacting climatic conditions.

Another point which indicates the power of internal forces is that outwardly similar plants of the same species, within a score or two of yards from each other, are deciduous at periods varying by many weeks and months. Haberlandt quotes Palaquium macrophyllum as a species which at Buitenzorg shows an independence of external meteorological conditions in so far that individual trees growing in the same neighbourhood throw off their old leaves and produce new ones during different months.

If one selects trees of Lagerstrœmia Flos-reginæ, Retz., Bridelia retusa, Spreng., or species of Canarium or Palaquium, he will find that though they exist alongside each other under conditions which are physically identical, yet the time of fall of old leaf, production of new leaf, and of flowers differs considerably in specimens of the same species. In the case of Bridelia retusa the variation is one of months, and to see individuals of this species on the same plot, some dropping their leaves, others quite bare, many in full old leaf, and others in full new leaf and flower impresses one with the significance of the internal forces.

Another consideration which may be put forward to indicate independence of external forces is the behaviour of the trees in respect to the dry period of the year. If there is one part of the year when the climatic conditions are likely to exercise their power it is the relatively dry period during February and March. It cannot be questioned that conditions favour excessive transpiration during that period, and one would expect that a species would, by preference, pass through its leafless phase at that time. But what do we find ? In the first place some deciduous species are in full possession of their new foliage during the hot dry season, as Bassia longifolia ; in the second place some produce all their new leaf when the temperature and dryness of the air is at the maximum, as with Swietenia Mahogani, Careya arborea, Ficus asperrima, Gmelina arborea, Sterculia Balanghas, Phyllanthus indicus, Spondias mangifera, Terminalia belerica, Sterculia Thwaitesii, Lagerstrœmia Flos-reginæ, and others, and finally trees of Albizzia procera and often of Pterocarpus echinatus defer their leafless phase until the wet cold months of June and July, when transpiration and assimilation are usually near the minimum. Such species show that they are either able to carry on their inherent foliar periodicities in the face of a periodic and exacting climate or that they are less plastic than others. It may be that they have, in the migration of species, found themselves at a place where the climate is not in harmony with their original periodicity, and time will be required for an adaptation to be accomplished. From these and other considerations, it may be concluded that the seeming irregularity is an expression of the autonomy of the species, and is not likely to be changed by the climate under consideration.

There are several other observations which seem to suggest that the internal factors are of great importance.

If one tree be selected and the length of its leafless phase be observed from year to year it may transpire that there is a variation considerably greater than what one expects to find. One species may vary from 32 to 96 days for its leafless phase, another may vary from 2 to 14 days during different years, or a particular tree may not always pass through a perfectly leafless stage each year. In dealing with the frequency of defoliation several cases have been cited which thus indicate an independence of environment. The differences in such behaviour cannot always be correlated with climatic differences, and may in a great measure be due to internal requirements only.

An interesting point was also observed in connection with cuttings of Erythrina indica. Several cuttings in October, 1903, about 4 feet long, were stripped of all leaves and put into ordinary soil for cultivation as a green manure. They soon burst into leaf, many of them continued without a break in full vigour, but a very large number dropped all their leaves and passed through the leafless period during February and March. Many regained their foliage. This may indicate that the fall of leaf from the trees is an inherent character and must be of a curious nature, since it is not much changed by propagation from a cutting, the cutting behaving like a tree though it is not a year old.

External Forces.

Our knowledge of the different behaviour of the same species at Buitenzorg and East Java, of the many well-known instances of acclimatization in various parts of the world, and the behaviour of introduced species in Ceylon, convince us that climate exerts a recognizable influence on the foliar and floral periodicities of tropical plants.

Previous observations have shown that certain species are not affected by the climatic periodicity, and those cases which indicate that the time of foliar activity is influenced by the climate can now be dealt with. The most striking fact which impresses one with the power of the dry period is that more than half of the deciduous endemic and indigenous species pass through their leafless phase from January to March. These species show a response to climate, in so far that in districts similar to Peradeniya they drop all their old leaves and remain leafless during a part of the hottest and driest season. During this period the leafless twigs of Bombax malabaricum, Eriodendron anfractuosum, Spondias mangifera, Careya arboreya, Gmelina arborea, Ficus Arnottiana, Berrya Ammonilla, Terminalia belerica, Cassia nodosa, Bridelia retusa, Lagerstrœmia Flos-reginæ, and numerous others give a barren appearance to the arborescent vegetation. With certain exceptions the deciduous trees seem only to recognize one dry period as against the alternating dry and wet months of the remainder of the year. Terminalia Catappa undergoes a complete change of leaf during the dry part of each monsoon, and other species are probably subject to foliar depletion twice during certain years.

Another fact which points to the effect of the Ceylon climate on foliar periodicity is seen in the behaviour of trees in the north of the Island. The majority of the Ceylon species of Diospyros are evergreen and grow in the wet and intermediate zones. There are two species, viz., D. montana, Roxb., and D. ovalifolia, Wight, which in the dry hot district between Madawachchi and Mannar are partially deciduous and pass through a semi-leafless phase prior to the beginning of the rainy season ; yet they are evergreen at Peradeniya.

That the climate of Ceylon has a decided influence on the periodicity of the deciduous species is obvious if one leaves the Peradeniya district in May and proceeds to the north of the Island, where there is very little rain in the south-west monsoon, and where the weather from January to October is relatively dry and hot. The defoliation and foliar repletion have been considerably delayed in the Vavuniya and Mannar Districts compared with Peradeniya, the species common to all districts dropping their leaves at times which differ by many weeks and months. In the northern districts so long as the plant drops its leaves during any of the eight or nine months the same climatic advantages, if any, will accrue.

The maximum number of species undergoing defoliation is always found to be coincident with the dry period in all parts of Ceylon, and it is not necessary to do more than refer to the various observations recorded in the section dealing with the leafless phase and the importance of the climatic factors.

In a tropical district like Peradeniya the foliar periodicity may be determined by internal and external factors, and each species must be considered separately. The more equable the climate in different parts of Ceylon the more conspicuously will the internal forces operate, and the more independent they will be of climatic influences. My statement at the British Association Meeting of 1902 that botanists desirous of studying the internal forces in plant life should select a tropical country other than Ceylon is still supported by the further results of this investigation.

In a general way it maybe said that the nearer to the tropics the more the personal equation influences the phenomena of plant life, and as we pass from the equator—north or south—the less the power of the internal forces and greater the power of climate in determining the periodicity of plant life.

Even in those parts of the tropics where there are definite seasons, the phenomena appear to be the outcome of climatic and individual forces. In more equable tropical zones, with the minimum climatic variation, the plant phenomena are almost entirely determined by the individual requirements.

Respecting the effect of internal and external factors the main points may be summarized as follows :—

(1) The foliar periodicity of deciduous trees is inherent in tropical and temperate zones since it is observable in all these areas.

(2) The more equable and tropical the climatic conditions the larger is the number of arborescent species and the larger is the proportion of the evergreen trees in the flora. (*Cf.* British and Ceylon tree flora.)

(3) The more marked the climatic periodicity the less the internal forces are obvious and the more evident are the external forces. At Buitenzorg, where the climate is relatively equable throughout the year, the power of the

internal forces is obvious on every hand. In East Java and in Ceylon the climate is not equable throughout the year, and the power of internal and external forces is to be seen in various degrees. In the temperate zone, the climatic periodicity is more strongly pronounced and the internal factors almost obliterated.

(4) There is evidence to show that a marked climatic periodicity in which a drought is involved tends to induce a partial deciduous phenomenon in trees which, under a less exacting climatic periodicity are evergreen, *e.g.*, Thespesia populnea, Sol., Diospyros ovalifolia, and D. montana. The same may be said of Tectona grandis in East Java and Buitenzorg.

(5) There is also evidence to prove that a species which is deciduous in its natural home where a climatic periodicity is pronounced, may, when introduced to other countries, retain its periodicity if a climatic periodicity prevails, or it may tend to become evergreen if the climate is equable throughout the year, *e.g.*, Poinciana regia at Buitenzorg, East Java, and Ceylon, and Schizolobium excelsum in Buitenzorg and Ceylon.

(6) The arborescent flora in a temperate zone is mainly deciduous, and it seems possible that those plants the periodicities of which were or have been made to coincide with the winter months are among the most likely to survive.

In the temperate zones the flora is mainly comprised of plants which have survived the exigencies of extremes of climate such as the carboniferous rocks and glacial epochs indicate, and which are even now annually subjected to the frosts of winter and dry heat of summer. On the other hand it can be asserted that the plants in the equatorial zones are the phylogenetic outcome of forms long existing there, since there has been an unbroken condition for the development of plants, undisturbed by glacial periods or by temperate zone winters.

8.—Advantages of Periodical Phenomena.

It is impossible to assign one reason only to explain why the various species undergo a leafless phase once or twice each year. In parts of Ceylon the conditions are favourable to growth throughout the whole year. The flora is mainly of an evergreen type, but many of the deciduous species select the driest period for their leafless phase. In the temperate zones only those trees the leaves of which are tough and leathery, or are surrounded with a thick cuticle, or are so constructed that transpiration can never be rapid, retain their leaves throughout the winter months. The advantages which accrue from a leafless period in Europe are obvious, and on the defoliation may depend the life of the species in such districts. The trees throw off their relatively thin leaves before the winter sets in ; if they did not they would probably soon be destroyed by the melting of the ice crystals formed within their tissues ; furthermore they could not obtain the water required to make good that lost by slow transpiration during cold months, owing probably to the temperature of the soil being against root activity and the absorption of the necessary quantities of water. But it is obvious that such forces can be left out of consideration when dealing with trees in Ceylon.

A period of rest is characteristic of most temperate zone herbaceous plants, such as annuals which rest in the seed stage, perennials resting by corms, bulbs, &c. This resting feature is met with in many Ceylon herbaceous plants, such as Oxalis corniculata, *L.*, species of Caladium and Amaryllis, Drosera peltata, Sm., &c., though there is perhaps not the same necessity for such a phase since the temperature and humidity are always more or less favourable to plant growth, and the soil of medium quality.

It has been pointed out that the deciduous species in Ceylon do not pass through their leafless period at the same time, but during any month in the year even in the same district. The tropical species may choose a limited period of a few days or weeks or longer for dropping their old leaves and for complete renewal of foliage. Trees classed as evergreens may undergo the same change within the year and the question often resolves itself, in the tropics, into one of the possible advantages which accrue from throwing off the old worn-out leaf tissues quickly.

There is, in this phenomenon, a withdrawal of materials from the leaves before they are allowed to fall; this is followed by a leafless period during which the assimilation of carbon compounds, circulation of materials and constructive metabolism generally, are at the minimum. This semi-stagnant period of relative rest is followed by one of great activity, first in the using up of store materials for production of new leaves, then in transpiration and root activity, due to the exposure of the numerous thin leaves and the absorption of water and plant food. The alternation of rest and activity is the principal feature in these phenomena, and species which exhibit it may thereby obtain certain advantages, though what the latter may be is by no means always clear.

There appear to be in Ceylon three possible sources of advantage, which may be of importance in this phenomenon, viz.—(1) checking the loss by transpiration during the drought; (2) throwing off worn-out tissues and useless ingredients; (3) functional changes during the different periods. With respect to the first question it has been pointed out, when discussing transpiration and foliar periodicity, that a reduction in the amount of water lost by transpiration is effected by species which behave similarly to Bombax malabaricum, Spondias mangifera, &c., but that in other cases the loss by transpiration may not be reduced but actually increased.

In the second case it is suggested that the defoliation of tropical species in a climate which is comparatively regular throughout the year is probably more a question of casting off useless ingredients and worn-out cells and tissues than anything else. It is well known that the leaves of nearly all our tropical trees do not possess a cambium, and they can therefore only obtain new tissues by casting off the old members and producing entirely new leaves. It is obvious however that the same change can be obtained by a monthly fall and production of leaf. With respect to the possible necessity of throwing off the useless chemical ingredients when they have accumulated beyond the desirable degree of concentration, it may be stated that the yellow leaves of Erythrina indica as they fall from the tree contain 7 per cent. of lime. Nevertheless, it is erroneous to suppose that trees when throwing off their old yellow leaves are casting off members containing hardly any valuable food ingredients. Mr. Bruce analyzed several of the yellow fallen leaves of the common dadap (Erythrina indica) and found that they contained no less than 1·4 per cent. of nitrogen, 0·56 per cent. of potash, and 0·11 per cent. of phosphoric acid. These ingredients are not available in large quantities in Ceylon soils and the loss to the plant, temporary though in some cases it may be, is one which is not always seriously considered.

The main advantages are, however, probably to be associated with the change in functional activity of parts of the plants. It is not necessary that the leaves be continually exposed to light in order to successfully carry on the various functions of the plant. Experiments with various plants have proved that when light is supplied intermittently to the assimilatory organs the various functions are carried on as effectively as when light is continuously supplied. And the same may be said of our deciduous species, the leaves of which may be exposed to light for a varying number of months each year. By passing through the various stages of leaf-fall, leaflessness, and foliar renewal the assimilatory organs of the plant become subject intermittently to the stimulus of light, and on this depends the varying activity of many functions.

The variation in the activity of certain functions due to annual defoliation may be attended with many advantages. The plants obtain a period of rest as far as assimilation of carbon compounds is concerned, and the check to the transpiration current will most probably have an appreciable effect on the metabolism within the parenchymatous elements. The question of division of labour is also one which may be considered. During the resting period many changes already mentioned by Schimper are taking place. These changes are necessary and may be required to be effected before foliage is renewed in order to avoid stagnation or general interruption. During the beginning and early period of the leafless phase the cambium is comparatively inactive, and the growth which takes place will therefore consist more in the thickening of the walls and general strengthening of the existing elements than in the production of new cells. During the end of the period of defoliation there is usually formed a series of closely set thick-walled elements which contrast sharply with those formed when the new leaves are produced.

The above are a few of the possible advantages which may be associated with the foliar phenomena in the tropics, but it must be remembered that no matter how significant the advantages may be, they have not, in Ceylon, resulted in a wide distribution or persistence of a large number of deciduous species. The evergreen trees, which do not show periodic foliar phenomena in the sense that the deciduous trees do, but maintain a more or less regular rate of leaf, flower, and root activity throughout the year, comprise the greater part of the tree flora of this Island.

9.—Relation of Foliar, Floral, and Fruit Periodicities.

With most Ceylon evergreens the production of flowers is usually subsequent to that of new leaves. It is not possible, owing to insufficient information, to describe the relationship between flower and leaf production in all our deciduous species, but if one tabulates the observed results certain definite cycles are found to be characteristic of known species.

Out of twenty-one recorded species it is interesting to find that in eight of them, viz., Careya arborea, Sterculia colorata, Bombax malabaricum, Erythrina indica, Gmelina arborea, Gyrocarpus Jacquini, Chickrassia tabularis, and Spondias mangifera the flowers are produced when the tree is perfectly leafless and the production of flowers does not usually occur after the tree is in full leaf.

In other four species the flowers always appear with the young leaves as in Dalbergia frondosa, Stereospermum chelonioides, Vitex Leucoxylon, and Sterculia fœtida.

In other three species the production of flowers is delayed until all the leaves have been produced. In Melia dubia the flowers appear soon after the new leaves, but in the case of the other two species, Bridelia retusa and Lagerstrœmia Flos-reginæ, a considerable time may elapse between the full leaf and flowering periods. Most of the deciduous species in which the relationship of these periodicities has not been observed probably belong to this group.

Other species show a mingling of the two periodicities in various ways. For instance, some trees of Albizzia stipulata and Schleichera trijuga produce their flowers with the new leaves and continue to do so when the tree is in full leaf. Others such as Pongamia glabra, Phyllanthus Emblica, and Chloroxylon Swietenia commence to produce flowers when the trees are leafless and continue to do so until the new leaves are developed. In the case of Eriodendron anfractuosum, there is a copious production of flowers when the tree is leafless and flower production continues through the young leaf stage until the tree is in full leaf.

At Peradeniya the majority of plants whether arborescent, shrubby, or herbaceous seem to produce large numbers of flowers during the dry hot periods, though this is by no means the case with every species in the district.

The foliar, floral, and fruit periodicities of Bombax malabaricum are of more than usual interest. They show a division of labour or succession of periodicities which is only rarely observable in tropical plants. In the Peradeniya district old trees first allow their leaves to become discoloured and fall in December, and, after the trees have been leafless for a few weeks every twig bursts into red flowers, and these remain throughout the months of January and February. Fruits begin to mature in March, and by the end of April the seeds with their covering of white cotton are disbursed. When the flowering and fruiting periods are over the tree bursts into new leaf in April and May when rain can usually be relied upon. The various functions seem to each have an allotted period, and the periodicity is such that foliar and floral activities do not clash. The ripe fruits on the leafless twigs are exposed to the full force of the wind, the seeds better distributed, and leaf production occurs only when rain is plentiful.

These periodicities are of equal interest in Eriodendron anfractuosum, and it is as well to point out a common source of confusion in connection with the periodicities of this species and Bombax malabaricum. In both cases there is a copious production of flowers during the leafless period and an abundance of ripe fruits which burst and distribute their seeds before the tree regains its foliage. In the case of Bombax the fruits are from the flowers produced in the same year, but the fruits on the leafless twigs of Eriodendron are from the flowers of the previous year.

It should be pointed out that in most deciduous trees in which the flowers are produced when the tree is leafless, there is usually a time relationship between the floral and foliar activities on parts of the same tree. This can be seen in trees of Spondias mangifera, Chloroxylon Swietenia, and Chickrassia tabularis, growing in the open. These trees become defoliated from above downwards, the leaves on the lower twigs dropping a fortnight later than those on the upper twigs, and in all such cases the flowers are produced first on the twigs which shed their leaves first, and last on the lower twigs which become leafless the last.

The time relation between the production of flowers and leaves is characteristic of the species in dissimilar climates. This is seen if the periodicities of the species herein described are compared with those given by Brandis in his Forest Flora of India, particularly Gmelina arborea, Erythrina indica, Chloroxylon Swietenia, Careya arborea, Bombax malabaricum, Cassia fistula, &c.

10.—Foliar Periodicity of Fossil Plants.

Information concerning the foliar periodicity of trees when grown in dissimilar climates is of great value. It may help one to interpret the significance of structures in plants which have existed in palæozoic and mesozoic times. We have accurate knowledge of the periodicities of trees of the same species in different climates and the behaviour of the same species when introduced to different countries. The foliar periodicity, due in many cases to climatic forces, is to some extent responsible for the differentiation of rings of growth in the stem. The xylem differentiations met with in various fossil plants have been variously interpreted as indicating the equable or variable nature of the climates in which the plants have grown. Generally speaking, palæontologists have concluded that the complete and distinct differentiation of rings of growth in the stems of fossil plants indicated periodic foliar activity, and therefore a climatic periodicity, analogous to that in temperate zones; and also that the absence of the rings of growth was more or less associated with an evergreen type of vegetation such as one may expect to obtain in an equable or tropical climate. Many statements have been made apparently under the impression that foliar periodicity was inseparable from climatic periodicity, and the degree of distinctness of rings of growth in recent fossil woods has been frequently associated with a change from a relatively equable and tropical climate to one having a periodicity similar to that in middle Europe at the present day.

It is hardly necessary to draw attention to the erroneous idea that a period of foliar rest and activity is undiscernible in arborescent tropical plants in various parts of the world, or that the tropical vegetation is characterized by uninterrupted growth, and therefore the production of homogeneous secondary xylem. For in addition to the existence of about two hundred deciduous trees now growing in Ceylon one must acknowledge that there are regular periodicities in a large number of evergreen plants, in many of which the phenomenon is inherent and may lead to the production of a heterogeneous wood. The observations tabulated in this paper prove that foliar and other activities may be periodic in equable or tropical regions, that many plants pass through a leafless phase at any time of the year in a district like Peradeniya, and that the foliar periodicity exhibited may or may not lead to differentiations in the secondary xylem.

It will be shown in a later paper that in the tropics many deciduous trees do not show rings of growth, and further that quick-growing evergreens may show them. The results prove (1) that the differentiation of rings of growth in the stem is not confined to deciduous species; (2) that the foliar periodicity of trees is not necessarily due to the existence of a climatic periodicity; and (3) that rings of growth are not, in all cases, determined by foliar periodicities, neither are they a guarantee of the existence of a climatic periodicity. Such phenomena may be an expression of the autonomy of the plants dealt with, and one cannot be too cautious when considering the value of rings of growth as indicators of past climatic conditions. The subject of xylem differentiations is excluded from the present paper, but it is so closely associated with the foliar activity of trees in the tropics during our hot dry, hot moist, and dull wet months that the paper would have been incomplete without some reference to this subject.

11.—The Foliar Periodicity of Ceylon Endemics.

The endemic trees of Ceylon comprise no less than 274 species, or a little less than half the total number of arborescent species native to the Island. The foliar periodicity of the endemic plants is of great importance, as it shows the behaviour of plants which are known in Ceylon only, and from a study of these some light may be thrown on the general trend of periodicity in plants which for ages past have been accustomed to the climate prevailing here. It is more than probable that investigations of the Indo-Malayan flora will prove that many of our species, now considered endemic, are distributed in areas outside Ceylon, but such discoveries will not seriously affect the considerations dealt with in this paper. Throughout this paper the names and distribution of the plants as given in Trimen's Flora and the Peradeniya herbarium have been accepted as correct.

The endemic species are remarkable for the scarcity of deciduous forms, about ninety-four per cent. of the arborescent species being typical evergreens. The natural orders Sapotaceæ, Dipterocarpaceæ, Ebenaceæ, and the genera Semecarpus, Eugenia, Memecylon, and Symplocos, contain a remarkable high percentage of endemic species which grow into huge trees, very few of which are deciduous. The evergreen trees may produce a large quantity of new leaf once each year, some of them twice per year, but most of them are characterized by irregular leaf production during each month of the year.

Deciduous endemics.—Trimen mentions that Phyllanthus cyanospermus, Muell. Arg. (vol. IV., p. 27), a rare species found in the wet districts of Ratnapura and Ambegamuwa, and Allæanthus zeylanicus, Thw. (vol. IV., p. 102), found in the Peradeniya and Maturata districts, are deciduous. The deciduous character of these species has been confirmed, and the following species can now be added to the list of Ceylon deciduous endemics :—

Artocarpus nobilis, Thw.
Canarium zeylanicum, Bl.
Canthium macrocarpum, Thw.
Holarrhena mitis, Br.
Julostylis angustifolius, Thw.
Pericopsis Mooniana, Thw.
Sapindus erectus, Hiern.

Sterculia Thwaitesii, Mast.
Terminalia parviflora, Thw.
Dipterocarpus zeylanicus, Thw.
Hydnocarpus venenata, Gaertn.
Doona cordifolia, Thw.
Semecarpus Gardneri, Thw.
Debregeasia Wallichiana, Wedd. (=D. zeylanica, Hk.).
Ficus infectoria, Roxb. (endemic ?).

The total number of observed deciduous endemic species is therefore only 17, or less than 3 per cent. of the arborescent flora, or 6 per cent. of the endemic trees in Ceylon. Though the percentage number of deciduous indigenous species is higher than this, it is nevertheless small, and the vegetation therefore be regarded as mainly evergreen throughout the island.

Distribution of deciduous endemics.—The distribution of the deciduous endemic species is of considerable interest. From the facts related when discussing the question of transpiration and the curves showing an agreement between the defoliation of the deciduous species and the dry hot months of February and March, one may be inclined to anticipate that the endemic deciduous species would be wholly or mainly confined to the dry hot parts of the Island, and that very few would be common in the cooler moist districts. The distribution of the deciduous endemic species is, however, practically confined to the moist or very wet districts, only one species having been recorded for the dry and intermediate zones, viz., Sterculia Thwaitesii, Mast. These facts strongly suggest that the defoliation of species confined to Ceylon is not vitally associated with a high temperature or low humidity. They also compel one to realize that the foliar periodicity in the dry zones is one characterizing species which are not limited to this Island, but distributed throughout various climates in the tropical world.

It is advisable to give a detailed statement of the periodicity of this group, and the smallness in number of the species concerned allows one to do this.

Nature of defoliation and foliar renewal.—The species may be classified into three groups.

The first group comprises those species which become absolutely leafless, typical examples being Allæanthus zeylanicus, Thw., Canarium zeylanicum, Bl., Canthium macrocarpum, Thw., Holarrhena mitis, Br., Pericopsis Mooniana, Thw., Terminalia parviflora, Thw.

These species may undergo complete defoliation before any new leaf-buds appear, though this behaviour is rarely as conspicuous as in indigenous forms. The actual length of time during which they are leafless is very limited, and may be, for particular species, from 31st January to 17th February, 7th to 20th March, and 29th August to 4th September. The actual period required for a complete renewal of foliage is of course much longer. With trees of Canarium zeylanicum the leaves may commence to fall on the 3rd February and continue to do so until the 7th or 12th March, when the tree is quite leafless ; new leaf-buds appear from the 20th to the 28th March and the trees regain a complete outfit of mature leaves by the 11th April. Similarly for trees of Allæanthus zeylanicus, the period extends from 6th January to the 17th March, and with Terminalia parviflora from 10th February to 29th March. One tree of Holarrhena mitis effected complete defoliation and renewal within the month of March in 1902.

The phenomenon of foliar renewal is often so quick that the change of leaf on a tree of a particular species may be unnoticed.

The second class comprises those plants which though they may undergo a complete change of foliage within one or two weeks, are never absolutely leafless, on account of the production of new leaves on one part of the tree before all the old leaves have fallen.

Under certain circumstances trees of Terminalia parviflora and Canarium zeylanicum may behave in this way, but since they often become leafless they have been included in the former division. Endemic species belonging to the second division are such as Sterculia Thwaitesii, Mast., and Sapindus erectus, Hiern. One tree of Sterculia Thwaitesii, along the Museum road, Peradeniya, commenced to drop its discoloured leaves on the 16th January and continued to do so until the beginning of the following month ; during that time a few new leaves appeared and the dropping of old and production of new leaves continued, until by the 7th February the tree had put on a complete outfit of new leaves.

This entire repletion of leaf is effected within two to three weeks without the tree ever becoming leafless.

The third class includes trees which like Artocarpus nobilis, Thw., are never leafless, but produce large quantities of new leaf and become partially leafless at certain times of the year. This group borders on the evergreens.

This classification only holds good in a general way, and it must be recognized that the periodicity may vary during certain years and so make it possible to include the same species in more than one group.

Range in time of Foliar Periodicity.

The total range or period of time during which the deciduous endemics undergo foliar depletion and renewal is fairly wide, and extends from January to October. The endemic deciduous forms mainly recognize one dry hot period—January to March. Nine of the species undergo their change from January to March, one during March and April, one from February to April, one from April to June, one from August to September, and one from September to October. It is to be noticed that nearly all those species which are the most conspicuous and which become absolutely leafless at some time or other do so from January to April ; whereas those which are less conspicuous, such as Sapindus erectus, drop their leaves at a later date, and the species which is least conspicuous from a deciduous point of view and which has previously been referred to as bordering on the evergreens—Artocarpus nobilis—drops its leaves the last of all, in the cool moist month of October.

Variation of the same Tree in Successive Years.

In the table quoted hereafter it is obvious that there is often a fair constancy in the period at which a particular tree begins to show discoloured leaves and commences defoliation. There is, on the other hand, a considerable difference in the length of time during which a particular tree may be leafless in successive years. Julostylis angustifolius is an example of one which may not become absolutely leafless in a particular year though a leafless phase of several days' duration is what normally occurs. The differences to be noted in the synoptical table of dates quoted are not, perhaps, entirely due to corresponding differences in climate during the years in which the plants in question were under observation.

The relation of Foliar to Floral Periodicities in Deciduous Endemic Species.

Certain species have their foliar renewal closely followed or preceded by that of the flowers. Among these may be included Allæanthus zeylanicus. In this species the flower buds appear when the tree has shed only half its leaves, and during the time the tree is quite leafless the flowers are in full bloom; only after the new leaves have appeared do the flowers begin to wither and drop: a few flowers still exist when the tree has regained full new foliage. Canthium macrocarpum though bare in February puts on full new foliage and also flowers in March, and the full new leaf in April on Holarrhena mitis is followed by flowers in May.

Others produce the flowers long before the old leaves drop or after the new leaves have been produced: Julostylis angustifolius, Sterculia Thwaitesii, Sapindus erectus, &c.

These relationships may be better studied in the more numerous indigenous deciduous forms.

Endemics.

	Leaf-fall.		New Leaves appeared.	Leafless Period.	Flowers appeared.
	Commenced.	Finished.			
Holarrhena mitis, Peradeniya.					
1902 ...	Feb. 27	Mar. 18	Mar. 24	17 days	May 4
1903 ...	Feb. 20	Mar. 16	April 7	21 days	May 7
1904 ...	Feb. 14	Mar. 2	Mar. 17	15 days	April
1905 ...	Feb. 3	Mar. 1	Mar. 12	11 days	
Allæanthus zeylanicus, Peradeniya.					
1902 ...	Jan. 6	Jan. 31	Feb. 17	17 days	Feb. 28
1904 ...	Jan. 10	Jan. 30	Feb. 16	17 days	March 2
1905 ...	Jan. 30	Feb. 24	Mar. 17	20 days	
Canarium zeylanicum, Peradeniya.					
1902 ...	Feb. 3	Mar. 7	Mar. 20	12 days	
1904 ...	Feb. 4	Mar. 12	Mar. 28	16 days	
1905 ...	Mar. 4	Mar.	Mar.	—	
Pericopsis Mooniana, Peradeniya.					
1902 ...	Aug.	Aug.	Aug.	—	
1903 ...	Aug. 22	Aug. 29	Sept. 4	6 days	
1904 ...	Aug. 3	Aug. 20	Aug. 22	1 day	
Sapindus erectus, Peradeniya.					
1902 ...	May 9	May 30	June 6	6 days	
1904 ...	April 24	May 20	May 22	2 days	
Sterculia Thwaitesii, Peradeniya.					
1902 ...	Jan. 16	Feb. 7	Jan. 18	None	
1903 ...	Jan. 18	Feb. 6	Jan. 19	None	
1904 ...	Jan.	Feb.	Jan.	—	
1905 ...	Jan. 3	Feb. 1	Jan. 10	None	
Julostylis angustifolius, Peradeniya.					
1902 ...	Feb. 19	April 22	Mar. 12	None	
1903 ...	Feb. 1	Mar. 16	Mar. 28	12 days	
1904 ...	Feb. 7	Mar. 27	April 3	7 days	
1905 ...	Jan. 2	Mar. 20	Mar. 28	7 days	

	Leaf-fall.		New Leaves appeared.	Leafless Period.	Flowers appeared.
	Commenced.	Finished.			
Artocarpus nobilis, Peradeniya.					
1903 ...	Oct. 10	Nov. 13	Oct. 28	—	
1904 ...	Mar. Sept.	—	Mar. Oct.	None	
Debregeasia Wallichiana, Peradeniya.					
1904–05 ...	Dec. 30	Jan. 16	Jan. 25	8 days	
Dipterocarpus zeylanicus, Peradeniya.					
1901–02 ...	Dec. 2	Jan. 3	Dec. 30	—	
1902–03 ...	Nov.	Jan.	Nov.	—	
1903–04 ...	Dec.	Feb.	Jan.	—	
Hydnocarpus venenata, Peradeniya.					
1905 ...	Jan. 25	Mar.	Feb. 4	—	
Semecarpus Gardneri, Peradeniya.					
1905 ...	Feb. 3	Mar. 18	Mar. 3	—	
Doona cordifolia, Peradeniya.					
1905 ...	Jan. 14	Feb. 26	Feb. 3	—	
Phyllanthus cyanospermus, Peradeniya.					
1903 ..	March	Mar. 24	April 3	9 days	
Terminalia parviflora, Peradeniya.					
1902 ...	Feb. 10	Mar. 10	Mar. 12	2 days	
1903 ...	Feb. 12	Mar. 11	Mar. 16	5 days	
1904 ...	Feb. 2	Mar. 3	Mar. 8	4 days	
1905 ...	Feb. 15	Mar. 25	Mar. 29	3 days	

Other trees of Terminalia parviglora appear to be leafless for a longer time in the Peradeniya district.

At Henaratgoda, in 1902, several trees were in half new foliage on 11th February.

Canthium macrocarpum, Peradeniya.—During 1901 and 1902 the trees became leafless in February and produced new foliage and flowers in March.

Ficus infectoria. Deciduous. Trimen, Vol. IV., p. 92. Endemic?

12.—Foliar Periodicity of the Indigenous Species

There are in Ceylon nearly 380 arborescent indigenous species. In Trimen's Flora thirteen of these, the periodicities of which have since been confirmed, are described as deciduous. To these must be added the foliar periodicities of other sixty-five species. The total seventy-eight species are distributed among twenty-four natural orders. Nearly twenty per cent. of the indigenous species are deciduous, and in order to bring forward any possible relationship between the length of the leafless phase and the distribution of the species their periodicities have been described under the headings of the countries in which they are known to occur. The following is a plan of the arrangement adopted :—

1. Ceylon and India.
2. Ceylon, India, and Malaya.
3. Ceylon, India, Malaya, China, &c.
4. Ceylon, India, Java, China, and Japan.
5. Ceylon, India, and Java.
6. Ceylon, India, and Africa.
7. Ceylon, India, Malaya, Tropical Africa, &c.
8. Ceylon, India, and East Africa.
9. Ceylon, Malaya, and Australia.
10. Ceylon, Tropical Asia, &c.

There are several natural orders containing large numbers of indigenous species which grow into large trees. such as the Guttiferæ with 9, Apocynaceæ with 7, Boragineæ and Rhizophoraceæ each with 6, and Dipterocarpaceæ and Oleaceæ each with five species, but not one of these seven orders contains an indigenous deciduous species.

The following list shows the relative deciduous character of natural orders containing a varying number of arborescent indigenous species :—

No. of Indigenous Arborescent Species.		Natural Order.		No. of Indigenous Deciduous Species.
42	...	Euphorbiaceæ	...	5
33	...	Leguminosæ	...	14
28	...	Urticaceæ	...	14
18	...	Myrtaceæ	...	4
18	...	Rubiaceæ	...	3
13	...	Rutaceæ	...	1
11	...	Verbenaceæ	...	3
9	...	Lauraceæ	...	2
9	...	Meliaceæ	...	4
8	...	Tiliaceæ	...	1
8	...	Sterculiaceæ	...	3
8	...	Sapindaceæ	...	2
6	...	Combretaceæ	...	4
6	...	Sapotaceæ	...	2

It is a noteworthy fact that the natural order—Euphorbiaceæ—which possesses by far the largest number of arborescent indigenous species of any order in Ceylon should be characterized by so few trees which become leafless. The contention that the latex of these plants is of service during periods of drought or in districts which periodically suffer from want of rain would perhaps appear to be supported by this fact, as the species concerned are able to pass through the hot dry season without becoming leafless. Parkin* states that the latex from introduced species flows more freely and is thinner in the wet than in the dry season, and that in his opinion the laticiferous tubes act as water-stores; when there is plenty of moisture in the soil, more water is drawn up by the roots than is needed at once, and finds its way into the laticiferous ducts, to be drawn upon when required. The indigenous species which are deciduous contain very little, if any latex, a condition quite unlike that which obtains for the species of Hevea, Manihot, &c.,

* Parkin, J.; Caoutchouc or Indiarubber, Circular of the Royal Botanic Gardens, Ceylon, Series 1, Nos. 12, 13, 14, 1899.

introduced from other countries. The genus Ficus, however, contains a large number of deciduous species which possess well-developed latex tubes.

The natural orders which possess the largest proportion of deciduous species are the Urticaceæ and Leguminosæ respectively. The genus Ficus is remarkable for the high percentage of deciduous trees, the laticiferous system, and the leathery leaves of its species.

The annual periodicity of most of the indigenous plants here described is fairly constant from year to year. Observations upon plants which were hitherto regarded as being of the same species have shown a great variation in the manner and time of defoliation, and have led me to doubt whether the trees concerned are really of the same species. With the object of giving a systematic importance to the phenomenon of defoliation in the tropics, the following list has been compiled. It shows the distribution of the deciduous indigenous species in the Ceylon flora.

Anonaceæ.

Polyalthia coffeoides, Benth. and Hk.

Capparideæ.

Cratæva Roxburghii, Br.

Bixaceæ.

Flacourtia Ramontchi, L'Herit.

Malvaceæ.

Thespesia populnea, Sol.
Bombax malabaricum, D. C.
Eriodendron anfractuosum, D. C.

Sterculiaceæ.

Sterculia fœtida, L.
Sterculia Balanghas, L.
Sterculia colorata, Roxb.

Tiliaceæ.

Berrya Ammonilla, Roxb.

Rutaceæ.

Zanthoxylum Rhetsa, D. C.

Meliaceæ.

Melia dubia, Cav.
Dysoxylum binectariferum, Hk. f.
Chickrassia tabularis, A. Juss.
Chloroxylon Swietenia, D. C.

Sapindaceæ.

Schleichera trijuga, Willd.
Sapindus laurifolius, Vahl.

Sabiaceæ.

Meliosma Arnottiana, Walp.

Anacardiaceæ.

Odina Wodier, Roxb.
Spondias mangifera, Willd.

Leguminosæ.

Erythrina indica, Lam.
Erythrina ovalifolia, Roxb.
Dalbergia frondosa, Roxb. (= D. lanceolaria, L. f.)
Pongamia glabra, Vent.
Peltophorum ferrugineum, Benth.
Cassia Fistula, L.
Bauhinia tomentosa, L.
Adenanthera pavonina, L.
Adenanthera bicolor, Moon.
Acacia Suma, Kurz.
Albizzia Lebbek, Benth.
Albizzia odoratissima, Benth.
Albizzia stipulata, Boiv.
Albizzia amara, Boiv.

Combretaceæ.

Terminalia belerica, Roxb.
Terminalia glabra, Thw.
Anogeissus latifolia, Wall.
Gyrocarpus Jacquini, Roxb.

Myrtaceæ.

Eugenia Gardneri, Duth.
Eugenia operculata, Roxb.
Eugenia Jambolana, Larn.
Careya arborea, Roxb.

Lythraceæ.

Lagerstrœmia Flos-reginæ, Retz.

Rubiaceæ.

Sarcocephalus cordatus, Miq.
Stephegyne tubulosa, Hk.
Gardenia latifolia, Ait.

Ebenaceæ.

Diospyros Melanoxylon, Roxb.
Diospyros montana, Roxb.
Diospyros ovalifolia, R. Wight.

Sapotaceæ.

Bassia longifolia, L. Mant.
Mimusops Elengi, L.

Loganiaceæ.

Strychnos Nux-vomica, L.

Bignoniaceæ.

Oroxylum indicum, Vent.
Stereospermum chelonioides, D. C.

Verbenaceæ.

Gmelina arborea, Roxb.
Vitex altissima, L.
Vitex Leucoxylon, L.

Lauraceæ.

Litsea tomentosa, Heyne.
Litsea sebifera, Roxb. (= L. chinensis, Lam.)

Euphorbiaceæ.

Bridelia retusa, Spreng.
Phyllanthus Emblica, L.
Phyllanthus indicus, Muell. Arg.
Breynia rhamnoides, Muell. Arg.
Sapium indicum, Willd.

Urticaceæ.

Ficus hispida, L.
Ficus benghalensis, L.
Ficus altissima, Bl.
Ficus Trimeni, King.
Ficus retusa, L. Mant.
Ficus nervosa, Heyne.
Ficus Arnottiana, Miq.
Ficus Tsjakela, Burm.
Ficus infectoria, Roxb.
Ficus callosa, Willd.
Ficus asperima, Roxb.
Antiaris toxicaria, Leschen.
Antiaris innoxia, Bl. (see Trimen, Vol. IV., p. 97)
Artocarpus Lakoocha, Roxb.

1.—Ceylon and India.

	Leaf-fall.		New Leaves appeared.	Leafless Period.	Remarks.
	Commenced.	Finished.			
Bridelia retusa, Spreng.; Peradeniya.					
1901 ...	January	Feb.	March	—	Flowers appeared in June and July.
1902 ...	Jan. 4	Mar. 12	Mar. 24	11 days	
1903 ...	Jan. 6	Mar. 24	April 7	13 days	
1904 ...	January	Mar. 6	Mar. 20	13 days	
1905 ...	Jan. 2	Mar. 8	Mar. 16	7 days	
Careya arborea, Roxb.; Peradeniya.					
1900–01 ...	Dec. 14	Feb. 18	Mar. 18	28 days	
1901–02 ...	Dec. 18	Feb. 15	Mar. 15	28 days	
1902–03 ...	Dec. 20	Mar. 12	Mar. 24	12 days	
1903–04 ...	Dec. 16	Feb. 7	Mar. 8	29 days	
1904–05 ...	Jan. 3	Jan. 26	Feb. 4	8 days	
Dalbergia frondosa, Roxb.; Peradeniya.					
1902 ...	May 9	June 3	June 24	20 days	Flowers appear in June, before or with leaves.
1903 ...	May 13	June 6	June 25	18 days	
1904 ...	May 2	June 1	June 8	6 days	
Tree at Warriapola, Matale.	—	—	July 4	—	
Dysoxylum binectariferum, Hk. f.; Peradeniya.					
1902 ...	Mar. 3	Mar. 24	Mar. 20	—	
1903 ...	Feb. 28	Mar. 18	Mar. 6	—	
1904 ...	Feb.	Mar. 4	Mar. 1	—	
1905 ...	Feb.	March	March	—	

1.—Ceylon and India—*contd.*

	Leaf-fall.		New Leaves appeared.	Leafless Period.	Remarks.
	Commenced.	Finished.			
Diospyros ovalifolia, R. Wight.	August	Sept.	August	None	Partially deciduous in Northern Province.
Diospyros montana, Roxb. : Ceylon.	August	Sept.	August	None	do.
India ...	Feb.	March	March	—	According to Brandis.
Diospyros melanoxylon, Roxb.					
India ...	March	April	April	—	do.
Eugenia Gardneri, Duth ; Peradeniya.					
1902 ...	Feb. 3	Mar. 10	Feb. 26	—	
1903 ·	Mar. 18	April 11	April 7	—	
1905 ...	January	March	Jan. 19	—	
Ficus Arnottiana, Miq. ; Peradeniya. Tree A.					
1901–02 ...	Dec. 13	April 24	Feb. 3	—	
1902–03 ...	Dec. 17	Mar. 14	April 10	24 days	
1903–04 ...	Nov. 30	Mar. 22	April 7	16 days	
Peradeniya. Tree B.					
1901–02 ...	Dec. 23	Mar. 5	April 11	—	
1902–03 ...	Dec. 20	Mar. 3	April 7	35 days	
1903–04 ...	Dec. 21	Mar. 20	May 30	41 days	
Ficus asperrima, Roxb. ; Peradeniya. Tree A.					
1901–02 ...	Dec. 4	Dec. 28	Dec. 31	2 days	Very irregular at Peradeniya, and may be defoliated once or twice in twelve months.
1902–03 ...	Nov. 28	Dec. 24	Jan. 12	7 days	
1903–04 ...	Dec. 1	Dec. 26	Jan. 2	6 days	
Peradeniya. Tree B.					
1902 .	Mar. 4	Mar. 10	Mar. 18	7 days	
1903	Mar. 2	Mar. 9	Mar. 17	7 days	
	Oct. 1	Oct. 8	Oct. 11	2 days	
1904 ...	May 30	June 18	June 26	7 days	
1905 ...	Jan. 3	Mar. 20	Mar. 26	5 days	

1.—Ceylon and India—*contd.*

	Leaf-fall.		New Leaves appeared.	Leafless Period.	Remarks.
	Commenced.	Finished.			
Ficus altissima, Bl.; Peradeniya.					
Tree A.					
1902 ..	Mar. 1	June 6	Mar. 12	None	
1903 ...	Mar. 24	June 13	April 24	—	
	Sept.	October	Sept.	—	
1904 ...	Feb. 26	June 2	Mar. 16	—	
1905 ...	Feb. 24	—	Mar. 18	—	
Tree B.					
1901-02 ...	Nov. 28	Jan. 17	Dec. 28	—	
1902-03 ...	Dec. 5	Jan. 24	Dec. 28	—	
Ficus infectoria, Roxb.; Peradeniya.					
1902 ..	Feb. 12	Mar. 7	Feb. 25	—	
1903 ...	Mar. 5	Mar. 24	Mar. 16	None	
1905 ...	Mar. 12	April 14	Mar. 24	—	
Ficus Tsjakela, Durm.; Peradeniya.					
1902 ...	Jan. 14	Feb. 12	Feb. 22	7 days	
1903 ...	Jan. 21	Feb. 6	Mar. 1	22 days	
1904 ...	Jan. 16	Feb. 18	Mar. 16	25 days	
Meliosma Arnottiana, W. & R.					
Hakgala ...	January	January	Feb.	Several weeks	Flowers in June.
Phyllanthus indicus, Muell. Arg.; Peradeniya.					
1902 ...	Feb. 4	Mar. 10	Mar. 12	1 day	
1903 ...	Feb. 9	Mar. 13	Mar. 16	2 days	
1904 ...	Feb. 20	Mar. 16	Mar. 24	7 days	
1905 ...	Feb. 18	Mar. 6	Mar. 9	2 days	

1.—Ceylon and India—*contd.*

	Leaf-fall.		New Leaves appeared.	Leafless Period.	Remarks.
	Commenced.	Finished.			
Stereospermum chelonioides, D.C.; Peradeniya.					
Tree A.					
1901–02 ...	Dec. 13	Feb.	Dec.	None	
1902–03 {	Oct. 28	March	do.	do.	There are three trees known by this name. Their periodicities are described under headings A, B, and C. Tree A showed partial defoliation on more than one occasion within the same year.
	April 1	May	May	do.	
1903–04 ...	Dec.	March	Dec.	do.	
Peradeniya. Tree B.	Jan. 15	April 28	May 7	8 days	
1902 ...	Jan. 20	May 4	May 12	8 days	
1903 ...	Jan. 24	May 2	May 10	7 days	
Peradeniya. Tree C.					
1902 ...	January	May 4	May 10	5 days	Flowers appeared on May 13, 1902.
1903 ...	Dec.	May 1	May 7	5 days	
1904 ...	January	April 30	May 8	7 days	
1905 ...	do.	April	May		
Strychnos Nux Vomica, L.; Peradeniya.					
1903 ...	Jan. 23	Feb. 28	Feb. 3	None	
Terminalia glabra, W. and A.; Peradeniya.	—	—	—	—	Leaf-fall conspicuous during February and March, 1903.
Vitex altissima, L., f.	—	—	—	—	At Vavuniya in March, 1902, a tree shed a large part of its leaves.

1.—**Ceylon and India.**

	Leaf-fall.		New Leaves appeared.	Leafless Period.	Remarks.
	Commenced.	Finished.			
Vitex Leucoxylon, L. f.; Peradeniya.					
1901 ...	Feb. 1	Feb. 18	Mar. 6	15 days	New leaves and flowers appear together in March.
1902 ...	Jan. 30	Feb. 24	Mar. 10	13 days	
1903 ...	Jan. 28	Feb. 28	Mar. 7	6 days	
1904 ...	Feb. 24	Mar. 30	April 5	5 days	
1905 ...	Feb. 15	Mar. 23	Mar. 30	6 days	
Zanthoxylum Rhetsa, D.C.; Peradeniya.					
1902 ...	Mar. 2	Mar. 24	April 15	21 days	
1903 ...	Mar. 12	Mar. 22	April 8	16 days	
1904 ...	Mar. 16	April 10	April 26	15 days	
1905 ...	Mar. 2	April 4	April 21	16 days	

Acacia Suma, Kurz ; Peradeniya.

This tree is not very vigorous, and the recorded periodicity may be slightly different from that of a tree in a healthy state.

From 1901 to 1904 the leaves have become discoloured and commenced to fall during November in each year, and the tree is nearly leafless during February to April and regains its full foliage in May.

1.—*Ceylon and India.*

	Leaf-fall.		New Leaves appeared.	Leafless Period.	
	Commenced.	Finished.			
Anogeissus latifolia, Wall.; Peradeniya.					
1902 ...	Feb. 3	Mar. 10	Mar. 12	2 days	
1903 ...	January	Mar. 24	April 6	13 days	
1904 ..	March	March	March	None	
1905 ...	February	March	March	—	

In 1901 the leaves fell during February and March, and the tree was in full new leaf in April.

In 1904 new leaves were produced before all the old ones had dropped. It appears to be very variable at Peradeniya and may or may not become leafless.

In the Bintenne district in 1902, the foliar change took place in June, many of the trees being in new leaf and others leafless during that month.

1.—*Ceylon and India.*

	Leaf-fall.		New Leaves appeared.	Leafless Period.
	Commenced.	Finished.		
Bassia longifolia, L.; Peradeniya.				
Tree A.				
1901 ...	Dec. 4	Dec. 31	—	—
1902 ...	Dec. 8	Jan. 12	Jan. 14	1 day
1903 ...	Dec. 10	Jan. 12	Jan. 12	—
1904 ...	Dec. 12	Jan. 2	Jan. 3	—
Tree B.				
1901–02 ...	Dec. 9	Jan. 2	Jan. 8	5 days
1902–03 ...	Dec. 16	Jan. 6	Jan. 14	7 days
1903–04 ...	Dec. 28	Jan. 30	Feb. 5	5 days
1904–05 ...	Dec. 3	Jan. 1	Jan. 5	3 days

New leaves may appear before all the old ones have dropped.

Flowers appear soon after the new leaves.

During June several twigs drop their old leaves and produce new ones.

The defoliation in 1903–1904 was delayed, probably because of dry weather in November–December, 1903, and heavy rains in January, 1904.

At Bibile and Passara some trees were leafless, others dropping, and others in new leaf in May and June, 1904.

1.—Ceylon and India.

	Leaf-fall.		New Leaves produced.	Leafless Phase.	Remarks.
	Commenced.	Finished.			
Chloroxylon Swietenia, D.C.; Peradeniya.					
1902 ...	Feb. 27	Mar. 7	Mar. 11	3 days	Flower buds appear just before the new leaves.
1903 ...	Feb. 6	Mar. 19	Mar. 24	4 days	
1904 ...	February	Mar. 9	Mar. 27	15 days	
1905 ...	Jan. 8	Mar. 4	Mar. 17	12 days	

Another tree showed in 1901 and 1902 a heavy fall of old leaf in February and production of flowers and leaves in March. This tree also showed a minor activity in leaf production during the north-east monsoon in November and December.

1.—*Ceylon and India.*

	Leaf-fall.		New Leaves appeared.	Leafless Period.	
	Commenced.	Finished.			
1903 ...	Jan. 30	June 5	Mar. 1	—	
1904 ...	Feb. 3	June 9	Mar. 2	—	
1905 ...	Feb. 12	July	Mar. 4	—	
Ficus bengalensis, L.; Peradeniya.					
1902 ...	Feb. 5	June 3	Mar. 5	—	

During each of the years 1902–05 this tree commenced to drop its leaves first on the eastern side only, and the leafless twigs on that side put on a full complement of new leaves before leaf-fall commenced on the western side.

1.—Ceylon and India.

	Leaf-fall.		New Leaves appeared.	Leafless Period.	
	Commenced.	Finished.			
Flacourtia Ramontchi, L'-Herit.; Peradeniya.					
1901-02 ...	Dec. 18	January	Dec. 21	—	
1903 ...	April	—	May	—	
1904 ...	January	February	January	—	
	Sept.	Oct. 1	Oct. 14	13 days	
1905 ...	January	February	January	—	

This tree along the new Oreodoxa drive is most erratic.

1.—*Ceylon and India.*

	Leaf-fall.		New Leaves appeared.	Leafless Period.	
	Commenced.	Finished.			
Ficus Trimeni, King; Peradeniya.					
1900-01 ...	Dec.	March	Jan.	—	
1901-02 A. ...	Nov.	Feb.	Jan.	—	
1901-02 B. ...	June	October	August	—	
1902-03 A. ...	Nov.	March	Jan.	—	
1902-03 B. ...	July	October	Sept.	—	
1903-04 ...	Nov.	March	Jan.	—	
1904-05 ...	Dec.	March	Jan.	—	

The behaviour of this tree is rather peculiar. It appears to be subject to partial or complete defoliation during the windy weather in December and January and again in June and July. In neither case does the tree become absolutely leafless, new leaves appearing before all the old ones have dropped. An account of the behaviour of this tree for 1901 and 1902 is here given.

The leaves began to fall on 18th November, 1901, and on 6th December the tree was one-quarter bare. From the 14th to 20th December, during very windy weather, there was a very heavy fall of old leaf. The tree had dropped nearly all its old leaves on January 24, but new leaves had already appeared on many twigs, and by the 15th February the tree was in full foliage. On the 20th June there was again a conspicuous fall of old leaf, many twigs becoming quite leafless; the tree remained in this condition until the end of October; after that month the leaf-fall again commenced, and a conspicuous defoliation was effected in November.

1.—*Ceylon and India.*

	Leaf-fall. Commenced.	Finished.	New Leaves appeared.	Leafless Period.
Gardenia latifolia, Ait.; Peradeniya.				
1903	... Mar. 22	... May 18	... Mar. 28	... None
1904	... Mar. 26	... May 19	... Mar. 30	... None
1905	... Mar. 2	... May	... Mar. 16	... None

The leaves fell from individual twigs, and new leaf buds appeared almost immediately afterwards.

Litsea tomentosa, Heyne; *Peradeniya, 1901–1904.*—This tree is usually regarded as an evergreen. It undergoes complete defoliation annually during the months of April and May. Leaf production commences in the early or latter part of April, and the tree is in possession of full new foliage before the end of May.

Polyalthia coffeoides, Bent.; Peradeniya, 1902.—This tree commenced to shed its leaves on the 14th January, but up to the 7th April only one-quarter of the old leaves had dropped. On this date the leafless twigs showed a development of new leaf. The dropping of old and production of new leaf continued throughout the month of April, and this species is therefore on the border land of the deciduous and evergreen classes. It is the only member of the Anonaceæ in which this phenomenon has been observed, and is comparable to the partially deciduous character of Diospyros montana, Roxb., a dry zone member of the Ebenaceæ.

1.—Ceylon and India.

	Leaf-fall.		New Leaves appeared.	Leafless Period.	Remarks.
	Com-menced.	Finished.			
Odina Wodier, Roxb.; Peradeniya.					
1903 ...	October	Nov. 21	Nov. 30	8 days	A tree at Vavuniya shed its leaves, March, 1905.
Sapindus laurifolius, Vahl.; Peradeniya.					
1901 ...	Feb.	April	April	—	
1902 ...	Feb. 20	April 7	April 20	12 days	
1903 ...	Feb. 25	Mar. 20	Mar. 22	2 days	Flowers appeared on March 16.
Sterculia colorata, Roxb.; Peradeniya.					
1903 ...	Mar 10	Mar. 16	April 7	21 days	
Stephegyne tubulosa, Hk.; Peradeniya.	—	—	—	—	Shed a large number of leaves in March, 1902.

2.—Ceylon, India, and Malaya.

In this group there are eighteen species which exhibit a definite foliar periodicity, fourteen of them becoming absolutely leafless for a varying length of time.

It is noteworthy that here we are dealing with species which have a very wide distribution throughout the tropical world, and for this reason the following considerations are of much importance.

The range of time for their foliar activities is for most of the species limited to our hot dry season, January–March; true, a few commence to drop their leaves in

November and December, but as previously stated this is of no serious consequence. The months of February and March are coincident with the leafless phase of most of the species of this group.

The average length of time during which the trees of this group remain leafless is longer than for the members of the Ceylon and India group. For instance, we have Bombax malabaricum, the most remarkable for its leafless period, which extends with some trees from 79 to 96 days in each year; Erythrina indica (21 to 36 days), Gyrocarpus Jacquini (29 to 31 days), and species such as Berrya Ammonilla and Terminalia Belerica. The fact that these species are widely distributed may yet be correlated with the length of their leafless period and the adaptability of this to a hot dry season.

2.—*Ceylon, India, and Malaya.*

	Leaf-fall. Commenced.	Leaf-fall. Finished.	New Leaves appeared.	Leafless Phase.	Remarks.
Adenanthera bicolor, Moon; Peradeniya.					
1901–02 ...	Dec. 15	May 7	Jan. 21	None	
1903 ...	Jan. 12	May 8	Jan. 28	None	
1904 ...	Feb. 14	—	—	—	
Albizzia odoratissima, Benth.	—	—	—	—	At Vavuniya trees shed a large quantity of leaves in March.
Albizzia stipulata, Boiv.; Peradeniya.					
1901–02 ...	Dec. 30	Feb. 1	Feb. 11	9 days	The tree flowers in March and April after new leaves.
1902–03 ...	Dec. 28	Feb. 6	Feb. 28	21 days	
Antiaris toxicaria, Lesch.; Peradeniya.					
1902 ...	October	Nov.	Dec.		
	Jan. 3	Jan. 14	Jan. 24	9 days	Leafless in May to June at Passara.
1903 ...	Nov.	Nov.	Nov.	—	
1904 ...	August	Nov.	Nov.	—	

2.—Ceylon, India, and Malaya—*contd.*

	Leaf-fall. Commenced.	Leaf-fall. Finished.	New Leaves appeaerd.	Leafless Phase.	Remarks.
Antidesma Bunius, Spreng.; Peradeniya.					
1904-05 ...	March	March	March	—	
Antiaris innoxia, Bl.; Peradeniya.					
1901 ...	Feb.	March	March	—	
1902 ...	Feb. 3	Mar. 3	Mar. 4	—	
1903 ...	Feb. 6	Mar. 5	Mar. 6	—	
1904 ...	Feb. 10	Mar. 4	Mar. 7	2 days	
1905 ...	Feb. 4	Mar. 2	Mar. 10	7 days	
Berrya Ammonilla, Roxb.; Peradeniya. Tree A.					
1902 ...	Feb. 10	Mar. 3	Mar. 17	13 days	The defoliation is always from above downward.
1903 ...	Feb. 8	April 24	May 4	9 days	
1904 ...	Feb. 28	April 8	April 26	13 days	
Tree B.					
1901–02 ...	Dec.	Dec.	Dec. 28	—	Various trees show a foliar activity from December to February.
1902–03 ...	Dec.	Dec. 13	Dec. 28	14 days	
1930–04 ...	Nov. 27	Feb. 1	Feb. 4	2 days	
1904–05 ...	Dec. 18	—	—	—	
Bombax malabaricum, D. C.; Peradeniya. Tree A.					
1901–02 ...	Dec.	Dec. 14	Feb. 17	32 days	The time taken from the appearance of the leaf bud to expansion and development of full leaf may be a question of weeks and even months.
1902–03 ...	Dec.	Dec. 12	Feb. 28	45 days	
Tree B.					
1901–02 ..	Dec.	Jan. 24	May 1	95 days	
1902–03 ...	Dec.	Jan. 26	April 24	96 days	
1903–04 ...	Dec.	Jan. 30	April 21	79 days	
Tree C.					
1902–03 ...	Nov. 13	Jan. 28	Mar. 19	48 days	

2.—Ceylon, India, and Malaya.

	Leaf-fall.		New Leaves appeared.	Leafless Phase	
	Commenced.	Finished.			
Chickrassia tabularis, Juss.; Peradeniya. Tree A.					
1902 ...	Feb. 3	Mar. 3	Mar. 7	3 days	
1903 ...	Jan. 22	Feb. 26	Mar. 3	4 days	
1904 ...	Feb.	Mar. 5	Mar. 10	4 days	

Other trees in the Peradeniya and Henaratgoda districts are leafless during part of February and usually for a longer period than the above. In the Bibile district the leafless period was noticed in May and June, 1901. The flowers appear before the new leaves when the tree is bare.

2.—*Ceylon, India, and Malaya.*

	Leaf-fall.		New Leaves produced.	Leafless Phase.	
	Commenced.	Finished.			
Erythrina indica, Lam.; Peradeniya.					
1901-02 ...	Nov.	Feb.	March	—	
1902-03 ...	Dec.	Feb. 18	Mar. 23	21 days	
1903-04 ...	Dec.	Feb. 7	Mar. 27	36 days	
1904-05 ...	Dec.	—	—	—	

Most trees drop their leaves in December, January, and February, and red flowers appear during the last month and through March, while the trees are more or less leafless. The leaves appear from the middle of March to the end of April.

2.—Ceylon, India, and Malaya.

	Leaf-fall.		New Leaves produced.	Leafless Phase.	Remarks.
	Commenced.	Finished.			
Ficus nervosa, Heyne; Peradeniya.					
1901–02 ...	Dec. 23	Jan. 11	Jan. 15	3 days	Some of the old leaves may remain on the old twigs until new leaf has appeared.
1902–03 ...	Dec. 20	Jan. 10	Jan. 13	2 days	
Gmelina arborea, Roxb. ; Peradeniya.					
1902 ...	Feb. 5	Feb. 21	Feb. 28	6 days	Flowers are produced when the tree is leafless. Leafless trees have been seen at Vavuniya in May and at Peradeniya in April.
1903 ...	Feb. 14	Mar. 4	Mar. 16	10 days	
Gyrocarpus Jacquini, Roxb.; Peradeniya.					
1903 ...	Feb.	Mar. 24	April 24	29 days	In flower on March 24, 1903, when tree leafless. Often leafless in Northern Province in May.
1904 ...	Feb.	Mar. 27	April 30	31 days	
1905 ...	Feb.	Mar. 28	April 20	22 days	

2.—*Ceylon, India, and Malaya.*

	Leaf-fall.		New Leaves produced.	Leafless Phase.	
	Commenced.	Finished.			
Mimusops Elengi, L. ; Peradeniya.					
1902 ...	Feb.	Feb.	March	None	

The discoloured leaves fall rapidly in the last week of February; new leaves appear by the 3rd of March, and from that date the production of new foliage keeps pace with the fall of the old leaf, and by the first week in April a new outfit of foliage has been obtained. It undergoes annual defoliation, but on account of the absence of a leafless phase is often regarded as an evergreen.

2.—*Ceylon, India, and Malaya.*

	Leaf-fall.		New Leaves appeared.	Leafless Phase.	Remarks.
	Commenced.	Finished.			
Pongamia glabra, Vent.; Peradeniya. Tree A.					
1901–02 ...	Dec. 23	Jan. 21	Feb. 19	27 days	The flowers appear either with or prior to the new leaves.
1902–03 ...	Nov. 30	Jan. 4	Feb. 4	29 days	
1903–04 ...	Dec.	Feb. 10	Feb. 27	15 days	
Tree B.					
1903–04 ...	Dec.	Feb. 20	Mar. 5	11 days	
Terminalia Belerica, Roxb.; Peradeniya.					
1901–02 ...	Dec. 8	Feb. 12	Feb. 21	8 days	
1902–03 ...	Dec.	Feb. 6	March 5	26 days	
1903–04 ...	Dec.	Feb. 2	Feb. 14	11 days	
Sterculia Balanghas, L.; Peradeniya.					
1901 ...	Feb.	Feb.	March	—	
1902 ...	Jan. 31	Feb. 28	Mar. 13	12 days	
1903 ...	January	Jan. 24	Feb. 6	12 days	
1904 ...	Feb.	Mar. 11	April 10	29 days	
1905 ...	January	Feb. 2	Mar. 1	26 days	
Trema orientalis, Bl.; Peradeniya.					
1904 ...	Jan. 1	Jan. 26	Feb. 18	22 days	
1905 ...	January	Feb.	Feb.	—	

3.—Ceylon, India, Malaya, and China, &c.

	Leaf-fall.		New leaves appeared.	Leafless Phase.	Remarks.
	Commenced.	Finished.			
Adenanthera pavonina, L.; Peradeniya.					
1901–02 ...	October	Nov. 6	Dec. 8	31 days	The tree regains new foliage very slowly and is rarely in full new leaf before the end of February.
1902-03 ...	Oct. 12	Nov. 1	Dec. 10	38 days	
1903–04 ...	August	Oct. 28	Nov. 20	22 days	
1904–05 ...	October	Dec.	January	—	
Cassia Fistula, L.; Peradeniya.					
1902 ...	Jan. 4	Feb. 24	Mar. 10	13 days	Trees were in full flower at Anuradhapura and Dambulla on September 1, 1902.
1903 ...	Jan. 10	Feb. 27	Mar. 18	18 days	
1904 ...	Jan. 5	Mar. 3	Mar. 28	24 days	
1905 ...	Jan. 2	Feb. 27	March	—	
Ficus hispida, L.;	Feb.	March	March	—	
Ficus retusa, L.; Vavuniya.					
1902 ...	March	March	do.	—	
Lagerstrœmia Flos-reginæ, Retz.; Peradeniya.					
Tree A.					
1901–02 ...	Dec. 5	Jan. 24	Feb. 20	26 days	In the open; not shaded.
1902–03 ...	Dec.	Jan. 3	Feb. 5	32 days	
1903–04	Dec. 10	Jan. 8	Feb. 1	23 days	
1904–05 ...	Dec. 15	Jan.	Feb.	—	
Tree B.					
1901–02 ...	Nov. 16	Feb.	Dec. 18	—	The tree becomes nearly leafless in December. It is not in full leaf until the end of February.
1902–03 ...	Nov. 1	do.	Dec. 2	—	
1903–04 ...	Oct. 11	January	Oct. 28	—	
1904–05 ...	Nov. 20	—	—	—	

3.—Ceylon, India, Malaya, and China, &c.—*contd.*

	Leaf-fall.		New Leaves appeared.	Leafless Phase.	Remarks.
	Com-menced.	Finished.			
Tree C.					
1903 ...	January	Feb. 28	Mar. 5	4 days	
1904 ...	do.	Mar. 1	Mar. 17	15 days	
Tree D.					
1903 ...	Feb.	Mar. 5	April 7	32 days	
1904 ...	do.	Mar. 24	April 17	23 days	
Tree E.					
1903 ...	Feb.	Mar. 24	April 7	13 days	In flower, June
1904 ...	do.	Mar. 27	April 4	7 days	3, 1903.
Oroxylum indicum, Vent.: Peradeniya.					
1901 ...	January	Feb. 8	Mar. 22	40 days	
1902 ...	do.	Feb. 14	Mar. 30	42 days	
1903 ...	do.	Feb. 6	Mar. 24	44 days	
1904 ...	do.	Feb. 12	Mar. 30	44 days	

Other trees in the Peradeniya district show a heavy fall of leaf during January and February and a leafless period during February and March. One tree, probably not in full vigour, was leafless during November, 1901, and continued to produce new leaves during December, 1901, and right on until May, 1902, and is probably nearing its last day.

3.—*Ceylon, India, Malaya, and China, &c.*

	Leaf-fall.		New Leaves appeared.	Leafless Phase.	
	Com-menced.	Finished.			
Breynia rhamnoides, Muell.: Peradeniya.					
1901–02 ...	Dec. 12	Feb.	Jan. 25	—	
1902–03 ...	Dec. 3	Feb.	Jan. 28	—	

3.—Ceylon, India, Malaya, and China, &c.—*contd.*

	Leaf-fall.		New Leaves appeared.	Leafless Phase.
	Commenced.	Finished.		
Erythrina ovalifolia, Roxb.; Peradeniya.				
1902 ...	Feb. 4	Mar. 28	Feb. 24	—
1903 ...	Feb.	April 1	Feb.	—
Eugenia operculata, Roxb.; Peradeniya.				
1905 ...	Jan. 9	Feb.	Feb.	—
Litsea sebifera, Roxb.; Peradeniya.				
1902 ...	Feb. 26	April 3	Mar. 24	—
1902–03 ...	Nov. 9	April 1	Feb.	—
1904–05 ...	Dec.	April	Feb.	—
Sarcocephalus cordatus, Miq.; Peradeniya				
1904 ...	Feb. 1	March	March	—

4.—Ceylon, India, Java, China, and Japan.

	Leaf-fall.		New Leaves appeared.	Leafless Phase.
	Commenced.	Finished.		
Phyllanthus Emblica, L.; Peradeniya.				
1902 ...	Feb. 3	Mar. 3	Mar. 10	6 days
1903 ...	Feb. 2	Mar. 5	Mar. 20	4 days
1904 ...	Feb.	Mar. 10	Mar. 16	5 days

The flowers appear forming a compact inflorescence when the tree is leafless ; the leaves soon appear at the top of each inflorescence.

5.—Ceylon, India, and Java.

	Leaf-fall.		New Leaves appeared.	Leafless Phase.	Remarks.
	Commenced.	Finished.			
Artocarpus Lakoocha, Roxb.; Peradeniya.					
1901–02 ...	Dec. 3	Jan. 20	Jan. 14	—	
1902–03 ...	Nov. 26	Jan. 24	Jan. 3	—	
Ficus callosa, Willd.; Peradeniya.					
1902 ...	Feb.	Mar. 6	Mar. 4	—	Another tree of this species showed foliar activity in August, 1903.
1903 ...	March	April 28	April 2	—	
Schleichera trijuga, Willd.; Peradeniya.					
Tree A.					
1902 ...	Feb. 7	Mar. 3	Feb. 24	—	The flowers appear with the new leaves or immediately after them.
1903 ...	Feb.	Mar. 12	Feb. 21	—	
1904 ...	Feb. 19	Mar. 10	Feb. 26	—	
Tree B.					
1902 ...	Jan. 28	April 30	Jan. 31	—	
1902-03 ...	Nov. 8	May 16	Jan. 1	—	
1903–04 ..	Dec. 10	April	Jan. 12	—	
1904–05 ...	Dec.	—	—	—	

6.—Ceylon, India, and Africa.

There is one species belonging to this group of particular interest.

Cratæva Roxburghii, Br., Peradeniya.—This is a very slow-growing tree and is very conspicuous on account of the slow rate at which the old leaves fall and the new leaves appear.

1900–91. The tree commenced to shed its leaves in August and was almost leafless throughout November and December, 1900, and January, 1901. On the 3rd January only five new leaf buds appeared, and the tree remained with a single shoot in partial new leaf until the middle of March. Towards the end of April the tree was in full new leaf.

1901–02. On the 26th August, 1901, the discoloured leaves began to fall and continued to do so very gradually until by the 1st October the tree was bare. The tree remained leafless through the greater part of October and the whole of November; on the 2nd December two small leaf buds appeared on one twig, and on the 21st December five leaf buds were present. New leaves were not produced rapidly until the 14th February, the appearance of new leaf being quite as slow as the fall of the old leaf. On the 4th March the tree was in half new leaf, but it was not until the 31st March, 1902, that the tree was in full new leaf.

1902–03. On the 10th August, 1902, the leaves began to fall; the tree became leafless on the 25th October and remained in that condition until the 10th January, 1903. On the last date a few new leaves appeared on one twig only: on the 7th February new leaves appeared on a second twig, and full new foliage was regained by the 6th April.

1903–04. On the 30th August, 1903, the few yellow leaves commenced to fall, but the tree was not absolutely leafless until 28th November. On the 7th February, 1904, one twig put out a few new leaves and remained in this condition until the 9th March; on the 14th April the tree was in three-quarter new leaf, and by the end of April new foliage had been regained. The variability in length of leafless period is not of much consequence to a tree characterized by such a slow rate of activity.

From 1900 up to date I have not seen any flowers on this tree, though its age must be somewhat advanced. At Vavuniya, in March, 1902, I observed one tree shedding old leaves.

The following synopsis for the tree at Peradeniya is here given :—

	Leaf-fall.		New Leaves appeared.	Leafless Phase.	
	Commenced.	Finished.			
1900–01 ...	August	October	January	—	
1902 ...	Aug. 26	Oct. 1	Dec. 2	31 days	
1902–03 ...	Aug. 10	Oct. 25	Jan. 10	76 days	
1903–04 ...	Aug. 30	Nov. 28	Feb. 7	70 days	
1904–05 ...	Aug. 15	Nov. 12	Jan. 3	51 days	

7.—Ceylon, India, Malaya, and Tropical Africa, &c.

	Leaf-fall.		New Leaves appeared.	Leafless Phase.	Remarks.
	Commenced.	Finished.			
Albizzia Lebbek, Benth.; Peradeniya.					
1902 ...	Jan. 6	Mar. 3	Jan. 14	—	At Vavuniya trees shed their leaves in March, 1902.
1902–03 ...	Dec.	—	—	—	
Bauhinia tomentosa, L.					
1902 ...	Feb. 24	April	April ...	–	Flowered in April, 1902.
1903 ...	March	April	April ...	—	

Sterculia fœtida, L.—Observed trees at Peradeniya begin to shed their leaves on the 5th February, becoming leafless on the 14th, and remaining so for several days or even over one week. Other trees in the same district pass through their leafless phase during March.

At Elkaduwa in the Matale District trees may be seen just bursting into new leaf and flower in the first week in April. The flowers appear just before the leaves at a time when the tree is leafless.

8.—Ceylon, India, and East Africa.

Sapium indicum, Willd.; *Peradeniya.*—The leaves become discoloured in the latter part of December, and the fall of leaf takes place at such a rate that the tree is half bare by the 3rd January, but has not thrown off the whole of last year's leaf until the end of April. New leaves appear, however, early in January when only half of the old leaf has dropped, and the tree has usually put on a complete new outfit by the end of April.

Albizzia amara, Boiv.—A tree of this species was in 1896, according to Mr. Broun, then Conservator of Forests in Ceylon, leafless for a short time.

9.—Ceylon, Malaya, and Australia.

	Leaf-fall.		New Leaves appeared.	Leafless Phase.	
	Commenced.	Finished.			
Peltophorum ferrugineum, Benth.; Peradeniya.					
1901–02 ...	Dec. 2 June	January July	Jan. 14 June & July	— —	
1902–03 ...	Dec. 3 June	January June	Jan. 21 June	— —	
1904–05 ...	Dec.	Feb.	January	—	

10.—Ceylon and Tropical Asia, &c.

	Leaf-fall.		New Leaves produced.	Leafless Phase.	
	Commenced.	Finished.			
Eugenia Jambolana, Lam.; Peradeniya.					
1902 ...	Feb. 20	April	Mar. 10	—	
1903 ...	Feb.	March	Mar. 10	—	
1904 ...	Feb. 2	March	Mar. 14	—	
Melia dubia, Cav.; Peradeniya.					
1902 ...	Jan. 21	Feb. 1	Feb. 10	8 days	
1903 ...	Jan. 20	Feb. 16	Feb. 24	7 days	
1905 ...	Jan. 14	Feb. 23	Mar. 2	8 days	

Melia dubia is well distributed throughout the planting districts, and is conspicuous for the complete defoliation which it undergoes.

Observed species have commenced to drop their leaves on 21st January and have become leafless by the 3rd February. The new leaf buds can be seen within one or two days after complete defoliation, and the flowers immediately follow the new leaves.

Most trees in the Peradeniya district undergo their change of foliage from January to February each year, but occasionally they may be observed to pass through this phase in February to March.

Thespesia populnea, Soland ex Corr.—This is a species cultivated in the planting districts, where it does not usually pass through a conspicuous foliar phase, new leaves appearing irregularly throughout the year.

On the coral islands in the Gulf of Mannar this tree becomes half leafless during the dry period July to August, and puts on new leaf as soon as the rains arrive.

	Leaf-fall.		New Leaves appeared.	Leafless Phase.	Remarks.
	Commenced.	Finished.			
Spondias mangifera, Willd.; Peradeniya. Tree A.					
1901–02 ...	Nov. 18	Dec. 30	Mar. 24	83 days	Flowers were produced from the 6th to 24th February, 1903, and from 17th to 28th February, 1904.
1902–03 ...	Oct 28	Dec. 26	April 1	94 days	
1903–04 ...	Nov. 7	Dec. 28	April 10	102 days	
1904–05 ...	Dec. 6	—	—	—	
Tree B.					
1902–03 ...	Oct. 29	Dec. 28	Mar. 30	91 days	Flowers appeared on January 18th, 1903, and from 9th February to 7th March, 1904.
1903–04 ...	Nov. 13	Dec. 24	Apl. 3	99 days	
1904–05 ...	Dec. 8	Dec. 25	April	—	

Several other trees of Spondias mangifera have been under observation, and in only one case were there any conspicuous differences in foliar periodicity from those detailed above. This tree does not commence to shed its leaves until the end of December a (time when most other trees are leafless) and is in full flower and fruit on the 28th March.

This is a widely distributed species and is noticeable on account of its pronounced deciduous character. The trees of this species usually shed their leaves during December and remain leafless during January and February. The flowers always appear when the tree is leafless, and it is not until all the floral activity is long over that leaves are produced; it is therefore comparable with species of Stereospermum and several Malvaceous plants in this character.

Eriodendron anfractuosum, D.C.—This is a species distributed throughout Ceylon. During its first years and even up to ten years the tree grows relatively quickly. Trees only one year old show a partial defoliation in February at Peradeniya; the same trees showed defoliation in their second and third years from February to March. The defoliation on very old trees is often irregular, new leaves sometimes appearing before all the old ones have dropped.

In the Peradeniya district the old leaves fall during December, January, and February, and in the last month the trees usually possess nothing beyond mature fruits. The last year's fruits usually disperse their seeds embedded in white cotton while the tree is leafless (*Cf.* Bombax malabaricum); often, however, new leaves appear before the last year's fruits have disappeared. The new leaves appear with the flowers usually during April and May, after a leafless period of from two to six weeks.

At Henaratgoda and Colombo the periodicities agree with those observed at Peradeniya; in the Province of Sabaragamuwa many trees are leafless towards the end of May;

at Passara, in May and June, 1901, at an elevation of 2,800 feet, several trees were entirely leafless, and others in new leaf and flower; at Nawalapitiya and Dikoya several trees were leafless during March. 1902.

13.—Ceylon Indigenous Species in India.

In the foregoing lists a record of the periodicities of the deciduous species has been given. These usually refer to the behaviour of the plants in Ceylon, and it is now necessary to observe the behaviour of the same species in other countries.

Brandis, in his " Account of the Forest Flora of North-West and Central India," has given the periodicities of many species indigenous to Ceylon and India, and from references in his book and that of Kurz on " The Forest Flora of British Burma " the following details have been obtained.

In the dry parts and deciduous forests of India, Burma, Bengal, and South India, trees of Diospyros Melanoxylon, Diospyros montana, Gardenia latifolia, Odina Wodier, Phyllanthus Emblica, Schleichera trijuga, and Spondias mangifera usually shed their old leaves every year.

(1) *Diospyros Melanoxylon.*—The leaves are shed in March and April, and foliar renewal, accompanied by the production of flowers, is effected in April.

(2) *Diospyros montana.*—The leaves are renewed in February and March, and the flowers appear from March to May.

(3) *Gardenia latifolia.*—New leaves are produced in May; the wood has distinct rings of growth.

(4) *Odina Wodier.*—Trees of this species are leafless from January or February to June, and flowers appear while the tree is leafless. Kurz remarks that this species is frequent in all kinds of leaf-shedding forests all over Burma from Ava to Martaban down to Tenasserim and the Andamans (Vol. I., p. 321).

(5) *Phyllanthus Emblica.*—The tree is more or less leafless from February to April, and Kurz quotes it (Vol. II., p. 352) as being common in deciduous forests, especially the dry and open ones.

(6) *Schleichera trijuga* is a species which, according to Brandis (For. Fl., p. 105), sheds its leaves in February, but produces new leaves in March when most of the other trees of the dry forest are leafless.

(7) *Spondias mangifera* is common in the dry forests of many parts of India and Burma, and according to Brandis (p. 128) is one of the first trees to shed its leaves and the last to renew them, often remaining leafless until the rains have set in. The leaves are shed in November, and the flowers are produced in April.

It is interesting to note that most of the above seven species undergo defoliation and foliar renewal at approximately the same time of the year as at Peradeniya, the last three species showing almost exact agreement in time of periodicity.

Trees of Bombax malabaricum, Careya arborea, and Cassia Fistula, common to South India, Burma, and Bengal, also closely agree with trees at Peradeniya in the time of their leaf periodicities, as the following notes show.

Bombax malabaricum is leafless from November or December until April, and is covered with flowers from February to March, according to Brandis, p. 31.

Careya arborea.—According to Kurz, (Vol. I., p. 499) this is common in all the leaf-shedding forests, especially in the open, dry, lower mixed, and savannal forests of Burma; it is leafless during a part of the dry season, the new foliage appearing in March and April together with the flowers.

Cassia Fistula, which is common all over Burma and the adjacent leaf-shedding forests, is leafless for a short time in the dry season, the new leaves being produced in April and May.

Several other species have been observed to pass through a leafless state by Brandis in South India, Burma, and Bengal, and among them the following are noted.

Albizzia stipulata.—The young leaves appear in February and March.

Albizzia Lebbek.—The trees are partially leafless for some time in the hot season ; leaves produced in March and April, and sometimes a second flush in autumn.

Albizzia odoratissima.—The trees are never quite leafless, but partially so ; abundance of new foliage is produced in spring.

Albizzia procera is never quite leafless ; the new foliage appears in April and May.

Cratæva Roxburghii.—The old leaves may remain until the flowers appear ; the tree is usually bare for some time, and the young leaves appear with or without flowers in April and May.

Erythrina indica.—The old leaves are shed in autumn, young leaves produced in March and April, and flowers issue while the tree is leafless.

Gmelina arborea.—The leaves fall from February to April, new leaves issue in April and May, and the flowers appear generally while the tree is leafless.

Stereospermum cheloniodes.—Leaves fall in February and March, and new ones are produced in April.

Terminalia Belerica.—Leaves fall in February and March, and new foliage issues in April.

The periodicities of the following species found in various parts of India and described in the section dealing with indigenous species in Ceylon are also of interest.

Sterculia colorata.—In the forests along the outer valleys of the Himalaya, Burma, and in the dry deciduous forests it is leafless during the winter, flowers appear in March and April, and young leaves appear with or soon after the flowers.

Flacourtia Ramontchi.—On rocky hills and in open warm localities throughout India; sheds its leaves in January and February, and the tree remains bare until spring, the new leaves appearing in March and sometimes in May.

Chloroxylon Swietenia.—This is common in the Satpura range, Dekkan, and the Konkan ; it produces its new leaves in May, at about the time the old leaves fall.

Anogeissus latifolia.—A common tree in South and Central India; is leafless during the greater part of the dry season; from November the old leaves acquire a copper tint, fall in February, and new leaves appear in May.

Pongamia glabra.—Common in South and Central India, Burma, and Bengal; drops its leaves in April, but new leaves appear quickly.

Eugenia Jambolana.—This species is common in India; the new leaves are produced in March; in the Punjab the tree is not evergreen, the old leaves being shed in January and the new leaves appearing in March to May.

Eugenia operculata.—Common in parts of India; puts on its new foliage in April.

Shorea robusta, Gaertn., common in parts of India; is never quite leafless, but produces abundance of foliage in March.

Ficus bengalensis, F. infectoria, Ficus glomerata, and F. hispida; common in various parts of India; undergo their leaf change from January to April.

In concluding this paper I take the opportunity of expressing my gratitude to Dr. J. C. Willis, Peradeniya, for first suggesting the subject on my arrival in Ceylon and for help repeatedly given; to Dr. Treub, Buitenzorg, for much information concerning the climate and foliar periodicities in Java; to W. Nock, Esq., and H. F. Macmillan, Esq., for several notes; to the Surveyor-General, Colombo, for records of climate; and to M. Wright for various translations and reading proofs.

Description of Plates.

Plate XXV.—Map of Ceylon showing the average annual rainfall and temperature in various parts of the Island. The isotherms are in red lines.

Plate XXVI.—Diagrams showing the monthly and yearly average temperatures in Fahrenheit at (E) Kandy (Peradeniya), (D) Hakgala, (C) Colombo, (B) (Badulla), and (A) Mannar.

Plate XXVII.—Diagrams showing the monthly and yearly average rainfall in inches at (E) Kandy (Peradeniya), (D) Hakgala, (C) Colombo, (B) Badulla, (A) Mannar.

Plate XXVIII.—Diagrams showing the monthly and yearly average humidity in degrees at (E) Kandy (Peradeniya), (D) Hakgala, (C) Colombo, (B) Badulla, (A) Mannar.

The data on which the curves on plates XXVI. to XXIX. are constructed have been obtained from the Administration Report of the Surveyor-General for the year ending December, 1902.

Plate XXIX.—Diagrams to show the relation between the monthly humidity, rainfall, and temperature, and the number of species deciduous during each month.

Plate XXX.—Diagrams to show the relative monthly humidity and rainfall at Buitenzorg (Java) and Peradeniya.

Curve D. rainfall in inches; curve C. rainfall in millimetres.

REVIEWS.

The Dalbergias of S. E. Asia.

(The species of D. of S. E. Asia, by D. Prain ; Ann. R. B. G., Calcutta, X., Pt. 1, 1904.)

THIS is a splendidly illustrated and admirable monograph of this difficult genus of Leguminosæ. So far as the Ceylon Flora is concerned, our species are unaltered in scope or number, but the names of two are changed from those given in Trimen's Flora to earlier names, viz., D. Championii, Thw., to D. rostrata, Grah. (in Wall. Cat. No. 5,867, 1832), and D. monosperma, Dalz., to D. torta, Grah. (do. No. 5,873). All are figured (Plates 36, 76, 42) in Major Prain's monograph.

D. pseudo-Sissoo Miq. of Java, as suggested by Trimen, proves to be identical with D. rostrata. The distribution of this species should be given as found also in Borneo, Celebes, Java, Malay Peninsula, S. India. D. zeylanica, Roxb., proves as Trimen suggested to be the same as our D. lanceolaria, L. f. Major Prain gives this species, on the authority of a Thwaites's specimen, as " Central Province," whereas Trimen gives " dry low country." Thwaites's specimens are marked C. P. (Ceylon Plants), which, perhaps, explains the slip ; his localities include Deltota in the Central Province.

J. C. W.

A Revision of the Genus Pisonia.

(G. Bargagli-Petrucci : Le specie di Pisonia della Regione del Monsoni ; Lavori eseg. nel R. Orto Bot. di Firenze, Fasc. 1, p. 73, 1901.)

A REVISION of the eastern species. No change is made in the arrangement or name of the Ceylon forms (Trimen, Flora, III., p. 391).

J. C. W.

Localization of Thein in the Tea Plant.

(A. Nestler : Untersuchungen uber das Thein der Theepflanze : Jahresb. D. Vereinig. d. V. d. angewandten Bot. I., 1903, p. 54.)

USING the method described in vol. 1, p. 252, of the Annals, Nestler now shows that the tea plant contains thein in the seed, cotyledons, stem-bark, flower, and leaf. In the leaf it is found in the mesophyll, and possibly in the epidermis.

J. C. W.

Essential Oils.

(Semi-annual Report of Schimmel & Co., Leipzig, April, 1902.)

The useful half-yearly report of this well-known firm contains as usual much that is of interest to Ceylon. In the introduction mention is made of the growing feeling against the adulteration of essential oils—a practice only too common here, and one which is largely responsible for the depression of our citronella oil industry and the successful competition of Java. Of the Java oil Messrs. Schimmel & Co. remark: "we have obtained extraordinary results,........this product shows clearly what can be obtained by rational, expert cultivation and distillation of the crude material, for the species of plant used in Java is the same as in Ceylon. And yet what a vast difference between these two oils !

"........it is sincerely hoped that the excellent product may constantly increase in favour........so that the manufacture may be continued on a large scale." Further interesting details of the chemistry of this oil are given in the report. There is also a valuable account of the chemistry of Ceylon cinnamon oil.

Among other items of interest attention may be drawn to the article on champaca oil, in which it is stated that the oil distilled from the fresh flowers of the sapu, Michelia Champaca, has not been obtainable for years, in spite of a strong demand.

J. C. W.

Violent excretion of Water from the Leaves of certain Aroids.

(Hans Molisch : Hervorspringen von Wassertropfen aus der Blattspitze von Colocasia nymphæfolia (Caladium nymphæfolia Hort) Ber. d. Bot Ges. XXI., 1903, p. 381.)

In the case of Colocasia antiquorum a rapid excretion of drops of water from the young leaves, with such force as almost to resemble a tiny fountain, was observed by Muntingh as early as 1672. Molisch has closely examined the phenomenon in the case of C. nymphæfolia.

The excretion is most marked in young leaves, blades of which are not yet expanded, and takes place most actively at night, when as many as 163 drops per minute were observed by Molisch to spring from a single leaf tip. The drops of water escape from a special water-pore situated near the apex of the leaf.

R. H. L.

Observation on Growth in the Tropics.

(M. Burgew : Einige Wachsthumsbeobachtungen aus den Tropen. Ber. XXI., 1903, p. 435.)

THIS paper deals with the rates of growth of a species of Costus, of the young shoots of Brownea grandiceps and of Albizzia moluccana—all plants well known to residents in Ceylon. The Costus was observed to excrete large quantities of water by night from the inner surface of the leaf bases, and the evaporation of this water by day left a series of high water marks from which the daily rate of growth of individual internodes could be ascertained. Growth was rapid at night, but very slow by day. The average growth of a whole shoot during fifteen days in November was 5·4 cm. in twenty-four hours.

R. H. L.

Anatomical and Physiological Investigations in the Tropics.

(Anatomisch-physiologische Untersuchungen in den Tropen. Von Dr. Carl Holtermann.)

PROFESSOR Dr. Carl Holtermann worked at Peradeniya from November 29, 1900, to April 27, 1901. The paper under review should be regarded as a preliminary to a more detailed work describing the results of Holtermann's observations on the leaf-fall and transpiration of plants in Ceylon.

After describing the meteorological conditions and general characters of the flora prevailing in wet and dry districts in Ceylon, the author proceeds to dwell on the leaf-fall of tropical trees. He points out that in Ceylon there are no forests, the trees of which completely lose their leaves for a long period, and contrasts this with the forests of Tectona grandis (Teak) which he has seen in Java. He was particularly struck with the fact that with very few exceptions Ceylon possesses evergreen trees. He states that the flora of Ceylon contains, perhaps, 10–15 deciduous trees, and that none of them are endemic to the island; subsequent observations, which appear in this number of the "Annals of Peradeniya," will perhaps lead to a slight modification of this statement, though the impression which Holtermann describes is certainly correct. There are very few deciduous trees in Ceylon, and only a small proportion of the species which are periodically leafless are endemic. In the paper on Foliar Periodicity I intend to show that there are about 770 endemic species in Ceylon, over 280 of which belong to the arborescent class. About 17 of the endemic species and 78 indigenous species are deciduous and undergo a leafless phase for varying periods of time. Holtermann briefly describes the nature of the defoliation or foliar renewal in Tectona grandis, Odina Wodier, Melia dubia, Bassia longifolia, Ficus Trimeni, Ficus religiosa, Meliosma Arnottiana, Gyrocarpus Jacquini, Schizolobium excelsium, and species of Bombax, Spondias, Cochlospermum, Terminalia, Erythrina, &c. He points out that different species may pass through their leafless phases during the wettest or the driest months. He also makes a few observations on the relation of the annual rings of growth to foliar periodicity.

His observations on the transpiration of plants in Ceylon are of particular interest. He points out that at Peradeniya on ordinary days with a clear sky, evaporation commences after sunrise and remains feeble up to 10 A.M., but from this time it increases, until between 12 and 3 it reaches its maximum and then decreases until sunset, and subsequently dew is formed. Transpiration stops nearly or completely after sunset when saturation point is being approached. Microscopical examination of the plants convinced Holtermann that at Peradeniya during the moist warm period the stomata are closed during the night.

At Peradeniya, from January to March there is a dry north-east wind, and during this period transpiration is greater than at any other time and may even continue all through the night. The evaporation on damp days, when the air is saturated, is very slight or scarcely perceptible. In order to emphasize the great difference between the transpiration during hot dry and wet days, he states that Asplenium Nidus on misty days lost only from 0·00 to 0·21 gram of water per day, but on sunny days it transpired 3·50 grams.

Holtermann worked with various plants. Cymbidium bicolor, a common epiphytic orchid, was selected among others. This plant possesses thick stiff leaves (which are protected by a strong thick cuticle and a layer of cells running under the epidermis on the upper surface of the leaf) and narrow stomata. He proved that the transpiration from one plant of this species was, from the 23rd to the 27th January, both days inclusive, only 0·457 gram, or at the rate of about one gram in ten days. This means approximately one pound of water in thirteen years, a very small quantity indeed. Alstonia scholaris was also experimented with. The leaves of this commonly occurring tree are not xerophytic ; they possess normal stomata and internal tissues and a cuticle of average thickness. One shrub of this plant possessing 100 leaves lost during the 13th and 14th February, when the sky was cloudless and the temperature high, 1·24 grams ; but during the 15th and 16th, when rain was falling, only 0·06 gram of moisture was lost by transpiration.

Discussing the value of these and other observations Holtermann proceeds to state that there is between 12 and 2 o'clock on clear days in the tropics a much greater loss of water by transpiration than in Europe.

There are in the tropics a large number of plants which, though exposed to the full rays of the sun, only lose a small quantity of moisture by transpiration, *e.g.*, Euphorbia antiquorum, Cereus triquetra, and others. The leaves of these plants are small, and the green stems often carry on the greater part of the work of transpiration and assimilation. The stems of such plants are provided with a thick epidermis and deeply-sunk stomata. On a very hot day and in a very exposed place, Cereus triquetra lost by transpiration from 8 A.M to 6 P.M. 0·01 gram per quadratdecimeter. Holtermann also carried out experiments which proved that the tobacco plant lost twice as much moisture at Jaffna as at Peradeniya, and that the transpiration in the drier districts of north Ceylon is considerably greater than in the moist climate in the south-west of the Island. He also states that though a change of external conditions did not lead to any great difference in the transpiration from Cyanotis zeylanica, yet other plants which had been transplanted into pots transpired more than those cultivated under natural conditions, and showed striking changes in the anatomy of their roots.

H. W.

Periodicity of Growth in Thickness of Stems in the Tropics.

(Zur Periodicitat des Dickenwachsthums in den Tropen, von A. Ursprung, Botan. Zeit., Heft X., 1904.)

THE paper under review is an interesting contribution to our knowledge of the periodicity of plants in tropical areas and the relationship of foliar periodicity to anatomical differentiation. Ursprung regrets the absence of definite information regarding the periodic behaviour of most trees in the tropics, and points out the necessity for such knowledge before the zones of growth in the stem can be interpreted.

In the introduction Ursprung points out that the differences between spring and autumn wood depend upon the periodic formation of certain types of cambial products, and suggests that the relationship of the latter to foliar periodicity requires special consideration.

In discussing the origin of the periodicities of leaf activity he states that a knowledge of the climatic conditions which existed at the time of the origin of the species referred to would be valuable. He traces the foliar periodicity and zone formation in trees growing in uniform climates to internal forces, but allows that where the periodic climatic differences are great the external forces are of vital importance.

A description of the characters of the rings of growth of several trees common in Ceylon is given, and the differences of these when the tree is grown in the relatively equable climate of Buitenzorg and unequal climate prevailing in East Java, are described. Every species dealt with provides material sufficient for a separate paper, but space prevents my giving more than a summary of Ursprung's conclusions.

Tectona Grandis, L.—This species, in Buitenzorg, is never completely leafless, but retains a crown of leaves, though in East Java it passes through a leafless phase. The rings of growth in trees grown in East Java are more complete and distinct than those of trees grown in Buitenzorg. The climatic periodicity in East Java leads to a definite leaf-fall and zoned formation in the xylem. The rings are not necessarily annual, and when not complete are due to local activity of the cambium. The zone formation increases in sharpness in a centrifugal direction, probably on account of the defoliation in the early years being less complete than in the latter years. Observations in Ceylon have shown that certain species do not become defoliated annually until they have attained a certain age, and this may prove to be the case with teak.

Poinciana Regia, Boj.—Trees of this species are never, according to Smith, entirely leafless in Buitenzorg, though they are conspicuously so in East Java, and the rings of growth in trees grown at the latter place are more complete and distinct than those grown in Buitenzorg. I may add that at Peradeniya young trees are completely leafless every year, though old trees are sometimes only partially so.

Eriodendron anfractuosum, D.C.—Trees of this species are leafless at Buitenzorg and East Java, though the rings of growth are more distinct in the latter than the former place. At Peradeniya the trees drop their leaves in the first year.

Albizzia moluccana.—This is practically an evergreen tree with a definite foliar periodicity, and at Buitenzorg and East Java is never leafless, though at the latter place the rings of growth are more conspicuous than at Buitenzorg.

These observations prove—(1) that in Java the effect of a dry period is to make the zone formation in the wood sharper and more complete ; (2) that defoliation is not necessarily the only phenomenon, which will lead to the production of zones in the xylem, (3) in the same climate at Buitenzorg the sharpness of the rings of growth varies, and putting them in order, with the sharpest first and weakest last, we have the following : Tectona grandis, Poinciana regia, Eriodendron anfractuosum, Odina gummifera, Melochia indica, and Albizzia moluccana.

H. W.

Manual of the Trees of North America.

By Charles Sprague Sargent. (University Press, Cambridge, 1905.)

This book deals mainly with the characters of temperate zone trees. A map of North America (exclusive of Mexico) showing the regions into which the country is divided according to the prevailing character of the trees, and a glossary of technical terms are given. An analytical key based on the character of the leaves has been made, and the book is well illustrated on almost every page.

H. W.

The Flora of the Ceylon Littoral.

(A. G. Tansley and F. E. Fritsch : New Phytologist, Vol. IV., Nos. 1, 2, and 3, 1905.)

This is an account of the coast and mangrove flora of Ceylon by Messrs. Tansley and Fritsch, who recently worked at Peradeniya. The coast flora is divided into the Pes-capræ-Formation which extends to a few feet of high tide mark, and the Barringtonia-Formation or Beach Jungle, the characteristic plants in these sections being figured and described. The photographs of mangrove plants, Bruguiera gymnorhiza, Rhizophora conjugata, Sonneratia acida, Chrysodium (Acrostichum) aureum, and others are given, as well as accounts of the vegetation of the river at Matara and Balapitiya.

H. W.

Morphology of Angiosperms (Morphology of Spermatophytes, Part II.).

By John Merle Coulter and Charles Joseph Chamberlain.

(London, 1904.)

This work is issued in the form of a book of nearly 350 pages, profusely illustrated. It deals with the general classification of the Angiosperms, geographic distribution, fossil forms, phylogeny, and comparative anatomy of this group. Separate chapters are devoted to fertilization, the endosperm, and the embryo ; and the information given should be useful to students of flowering plants.

H. W.

The Comparative Anatomy and Phylogeny of the Coniferales, Part II., Abietineæ.

By Edward C. Jeffrey.

(Boston, January, 1905.)

A considerable amount of attention has been given to the resin canals in the different genera and the transfusion tissue. The Abietineæ should, according to the author, be regarded as a very ancient order of the Coniferales, and may even be the oldest living representatives of this group. The occurrence of resin ducts in the woody tissues and the cortex is regarded as primitive for the group. The group is divided into—(1) the Pineæ (Pinus, Picea, Larix, Pseudotsuga) and (2) the Abieteæ (Abies, Pseudolarix, Cedrus, Tsuga).

H. W.

On the Anatomy of the Roots of Palms.

By E. Drabble, D.Sc.

(Trans. Linn. Soc., II. Series, vol. VI., 1904.)

This paper deals with the internal characters of over sixty species of palms. The roots of more than seventy species were sent from Peradeniya to Dr. Drabble, and the work before us presents many new ideas, and is a comprehensive treatise on the anatomy of the roots of an interesting group of plants. Many of the species examined can be seen in the living state in the Gardens at Peradeniya.

H. W.

Publications.

The following publications have been issued since the last volume of the Annals :—

Circulars.

Vol. II.

15, 16, 17, 18, 19	...	Administration Reports for 1903.	
20	...	A Report on some Ceylon Timbers ...	H. Wright
21	...	Cacao Canker and Spraying in Ceylon	H. Wright
22	...	Plant Breeding	R. H. Lock
23	...	Ground Nuts in Ceylon ...	H. Wright
24	...	Varieties of Cacao at Peradeniya ...	R. H. Lock
25	...	Castor Oil Plant in Ceylon ...	H. Wright
26	...	Plant Breeding (Part 2) ...	R. H. Lock
27	...	Plant Breeding (Part 3) ...	R. H. Lock
28	...	Branch Canker in Tea ...	J. B. Carruthers
29	...	Canker (Nectria) of Para Rubber ...	J. B. Carruthers

Vol. III.

1	...	Notes on Dioscoreas (Yams) ...	H. F. Macmillan
2	...	The Chemical and Physical Properties of the Soils from the Tea Plots at the Experiment Station, Peradeniya ...	A. Bruce
3	...	The Chemical and Physical Properties of the Cacao Soils at Peradeniya ...	A. Bruce
4	...	Climbers	H. F. Macmillan
5	...	Zea Mays in Ceylon	H. Wright
6	...	Para Rubber in Ceylon ...	H. Wright and A. Bruce

7, 8, 9, 10, and 11, Administration Report, Royal Botanic Gardens, 1904.

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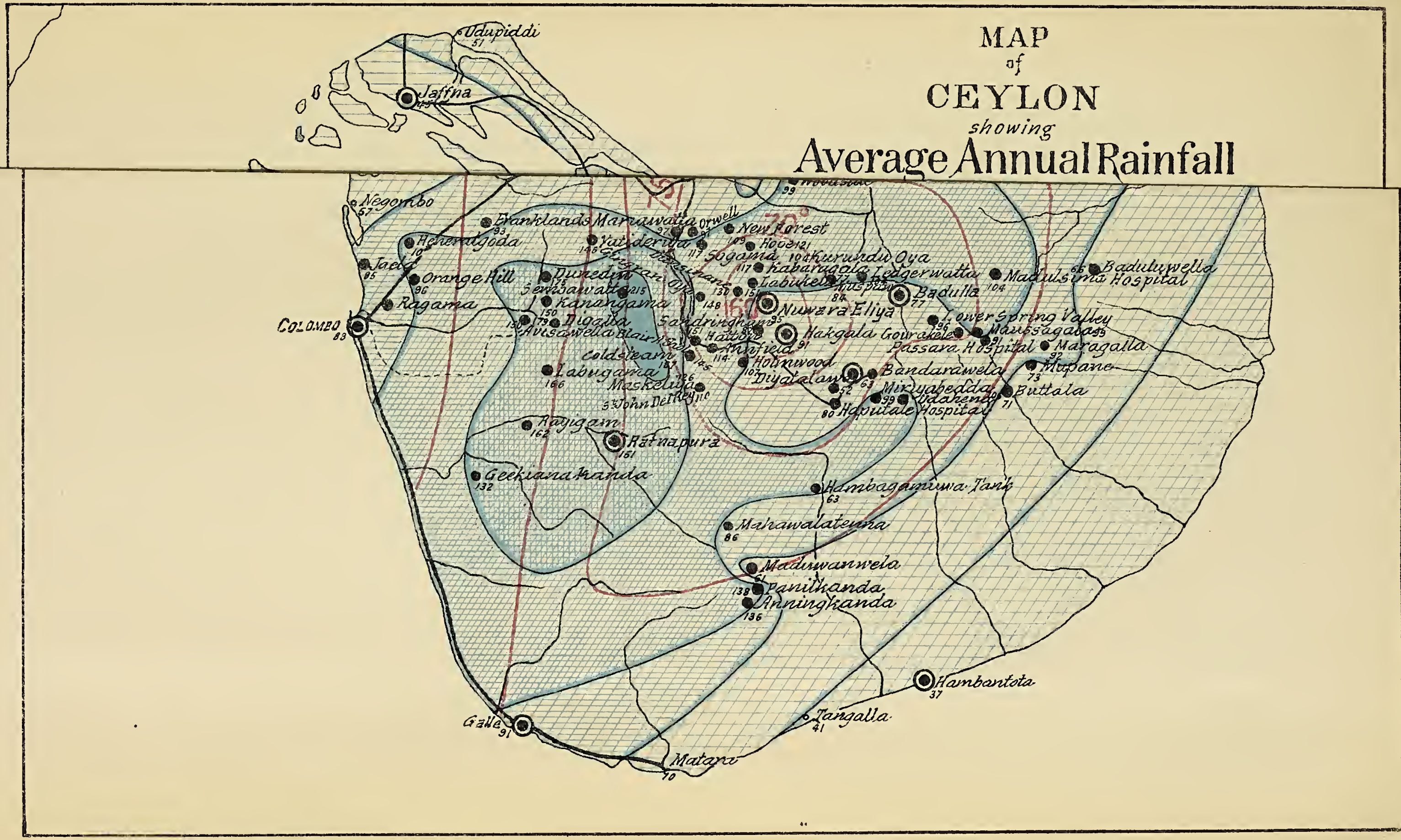

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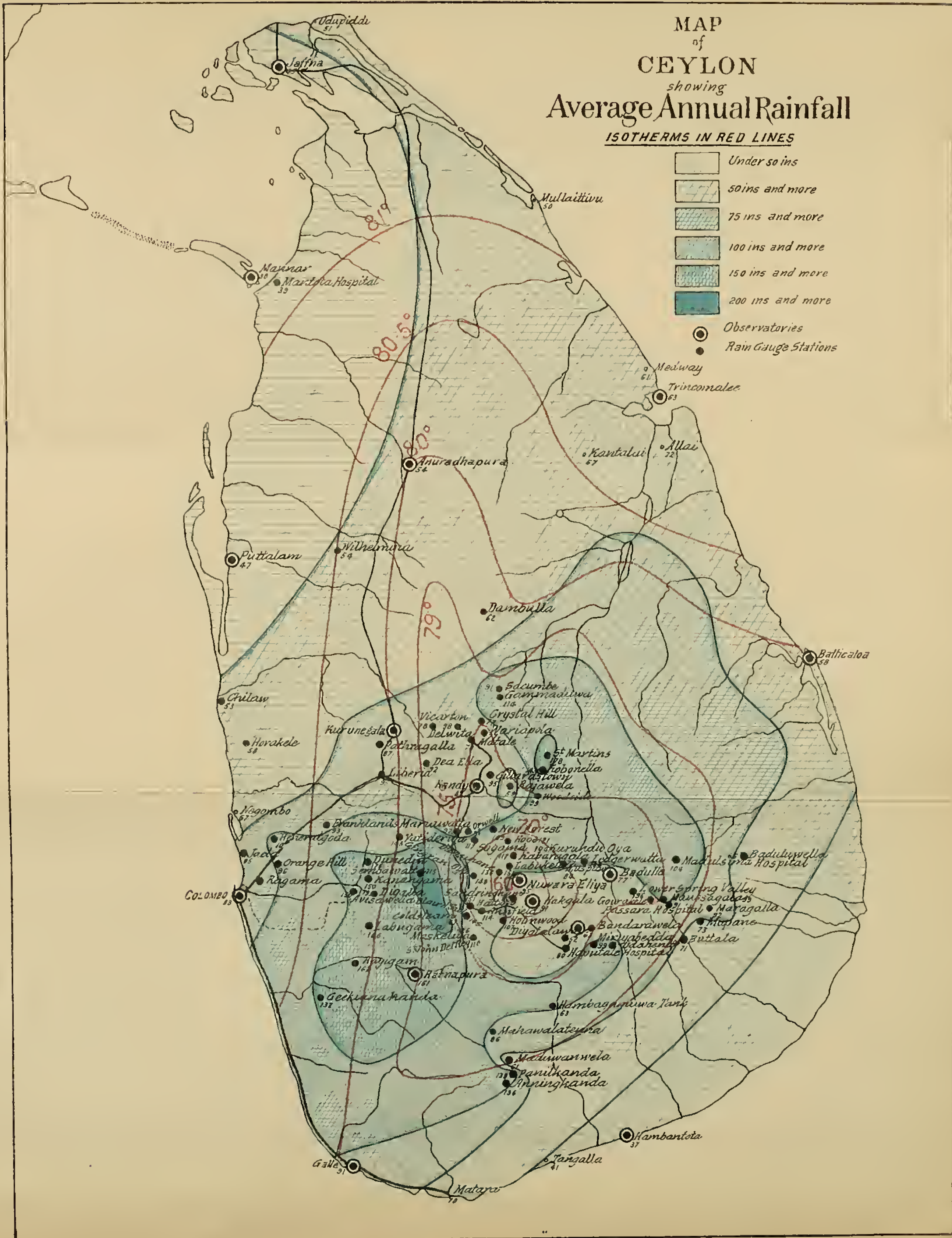
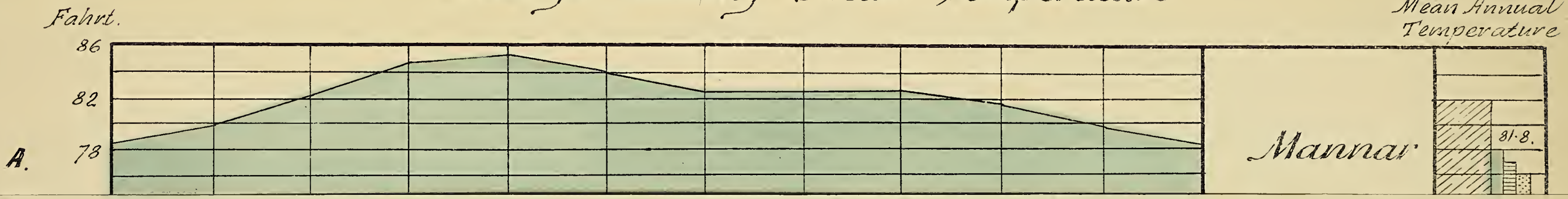

MAP
of
CEYLON
showing
Average Annual Rainfall
ISOTHERMS IN RED LINES
Under 50 ins
50 ins and more
75 ins and more
100 ins and more
150 ins and more
200 ins and more
Observatories
Rain Gauge Stations
Odupiddi
Jaffna
Mullaittivu
Mannar
Mantota Hospital
Medway
Trincomalee
Kantalai
Allai
Anuradhapura
Wilhelmina
Puttalam
Dambulla
Batticaloa
Chilaw
Kurunegala
Horakele
Pothragalla
Crystal Hill
Dea Ella
Kandy
St Martins
Negombo
New Forest
Kurundu Oya
Badulla
Baduluwella Hospital
Orange Hill
Ragama
Colombo
Nuwara Eliya
Hakgala
Passara Hospital
Maragalla
Bandarawela
Buttala
Labugama
Maskeliya
Ratnapura
Hambagamuwa Tank
Maduwanwela
Panilkanda
Anninghanda
Hambantota
Tangalla
Galle
Matara
80·5°
80°
79°
75°

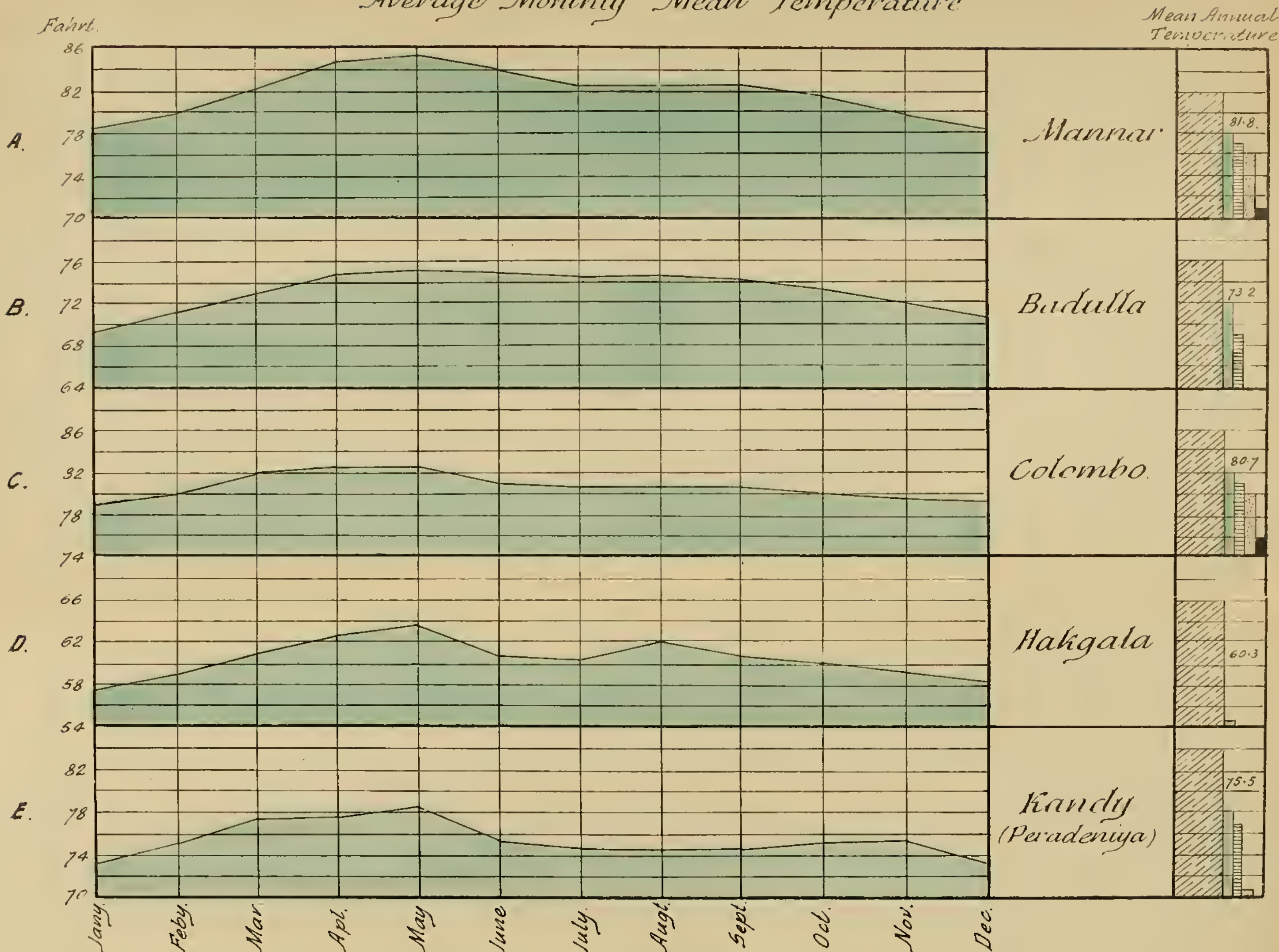
Temperature Curves.

Average Monthly Mean Temperature



Temperature Curves.

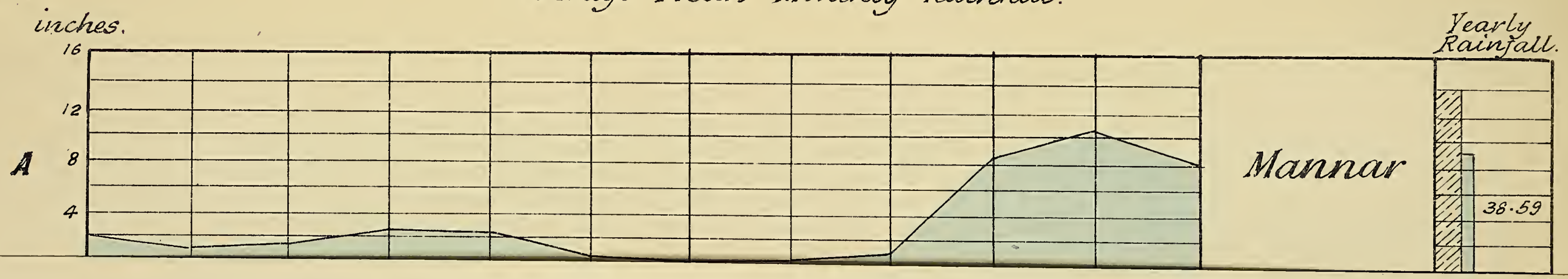
Average Monthly Mean Temperature



S. G. O. No. 106/05

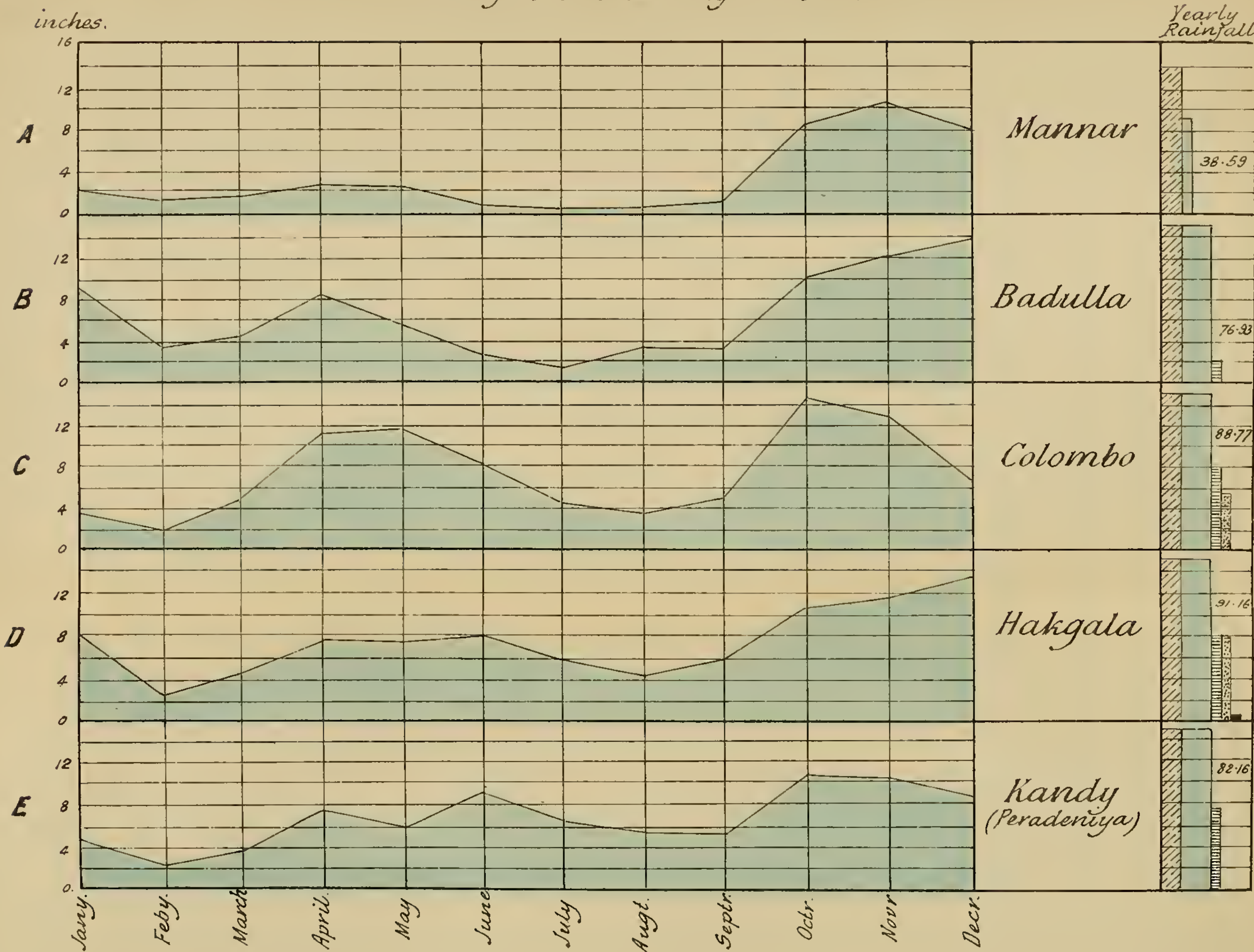
Rainfall Curves.

Average Mean Monthly Rainfall.



Rainfall Curves.

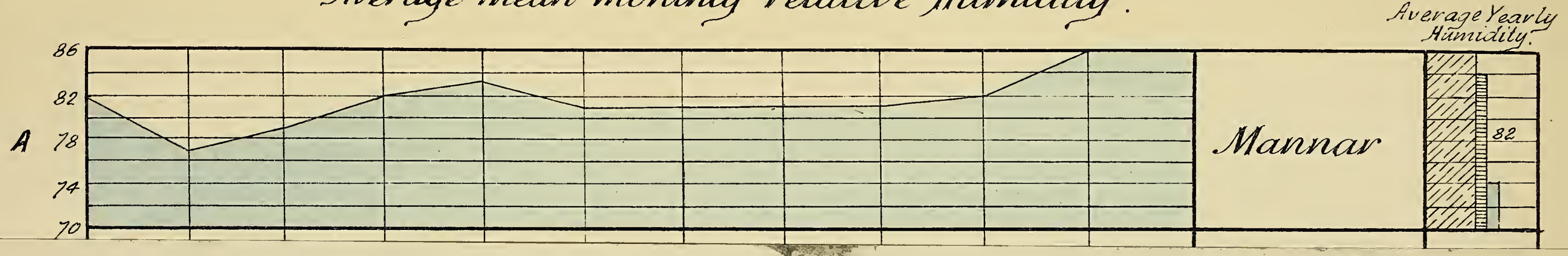
Average Mean Monthly Rainfall.



Lith S.G.O. Colombo. No. 107/05

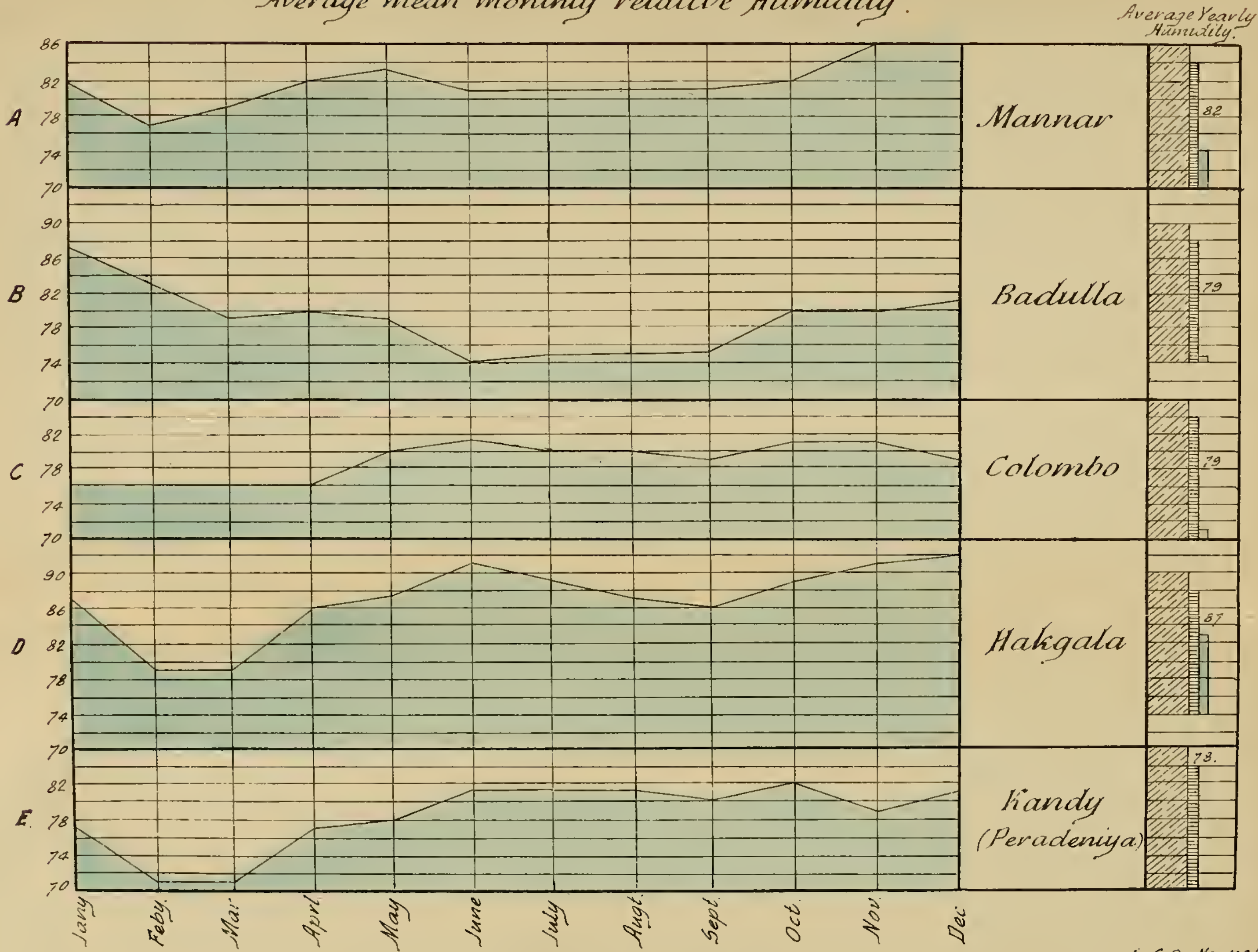
Humidity Curves.

Average mean monthly relative Humidity.



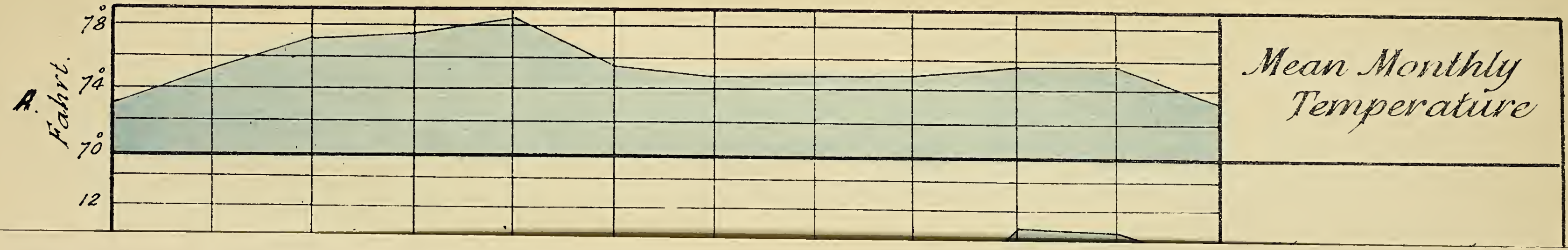
Humidity Curves.

Average mean monthly relative Humidity.

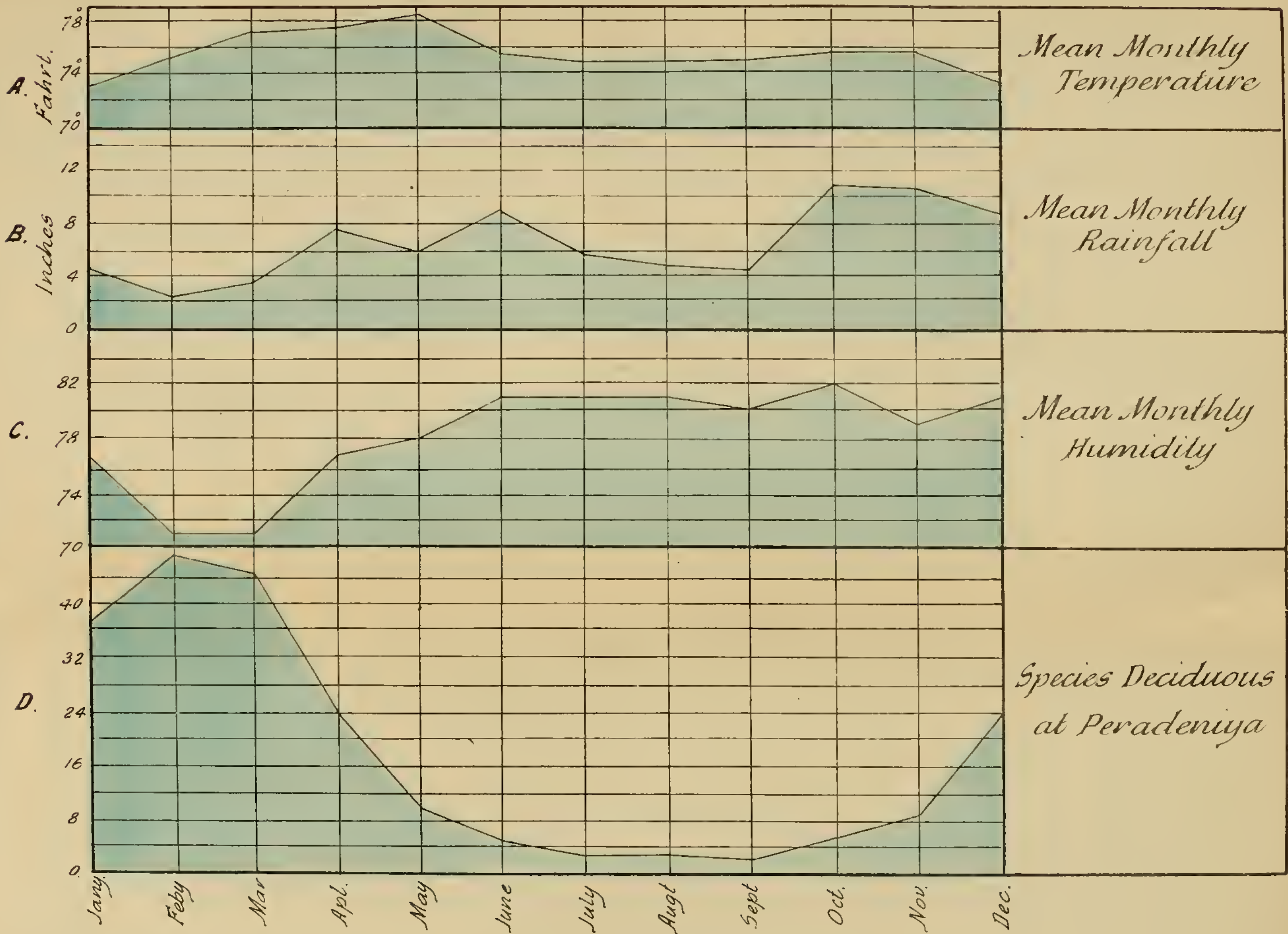


S. G. O. No 108/05

Relation between Humidity Rainfall and Temperature and the Number of Deciduous Species at Peradeniya



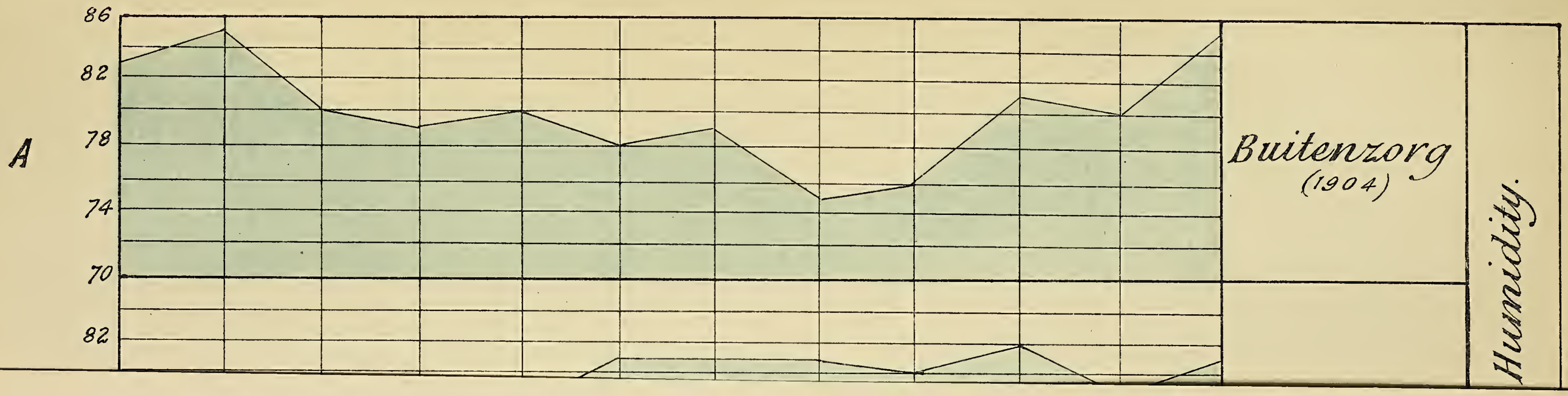
Relation between Humidity Rainfall and Temperature and the Number of Deciduous Species at Peradeniya



S. G. O. No. 109/05

Humidity and Rainfall.

At Buitenzorg & Peradeniya.



Humidity and Rainfall.

At Buitenzorg & Peradeniya.

Lith. S. G. O. Colombo. No. 140/05.

NOTICE.

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