Effect of Fertilisers on Seed Production by Hevea brasiliensis

G. A. WATSON and R. NARAYANAN

In one experiment sited on coastal alluvial clay the annual application of 4 lb per tree of ammonium sulphate increased seed production of Hevea brasiliensis *by 30% over a period of seven years, while in a second experiment on inland schist-derived soil an increase of about 80% was obtained over a period of three years. No response to nitrogen was obtained on a granite-derived soil where the tree nitrogen status was relatively high, but the application of potassium chloride to trees on this site significantly depressed seed production. Analytical data indicated that seed production will be favoured by a wide N/K ratio in the leaf.*

In the replacement of unproductive rubber by high yielding trees, seedlings of proved quality from high yielding parents provide a significant proportion of the recommended planting material (RUBBER RESEARCH INSTITUTE OF MALAYA, 1963a, 1964). Since suitable seed collection areas are limited in extent, and require particular maintenance, it is important to obtain from them the maximum yield of seed per acre (RUBBER RESEARCH INSTITUTE OF MALAYA, 1957).

In specially designed seed gardens, where a number of clones are closely intermixed, cross pollination increases seed production, but in monoclone areas the yield of seed is largely determined by the characteristics of the clone concerned. However, HAINES (1946) observed that the use of a complete NPK fertiliser more than doubled seed production in two out of three experiments reported, probably largely because of the effect of phosphorus, and this aspect of fertiliser usage has been studied further in the investigations reported in this paper.

In *ad hoc* work carried out over the years 1953—1955, quadrat sampling of seed fall in the plots of six NPK fertiliser experiments showed positive responses to nitrogen ranging from 20—120%, to phosphate ranging from 7—75%, and to potassium ranging from 8—29%. One negative effect of 20% due to phosphate was recorded, and negative effects due to potassium, ranging from 12—46%, were also found; further details of this work are recorded in a *Supplement* to this paper (WATSON AND NARAYANAN, 1964). Firm conclusions could not be made on the above data, because of large experimental variability, but since the indications were that major responses to fertilisers can be obtained it was decided to carry out more detailed investigations which are discussed below.

EXPERIMENTAL

In 1957 two experiments were laid down in established multi-clone seed gardens, one on coastal alluvium and the other on granite-derived inland soil, and in 1958 a third experiment was commenced in a monoclone area sited on a schist-derived inland soil; the soils can be taken as representative of the major rubber growing soil groups in Malaya. Details of the experiments are given in *Table 1* and in the following sections.

Experiment F

This experiment was sited in Gough Garden I, Isolated Seed Garden, where two planting systems have been used: a 20×10 ft rectangular system in a boundary isolation belt and a 60×5×5 ft double-hedge planting. Originally fourteen clones were present, planted in sequence, but seven clones were selectively poisoned in 1957 and 1959: the experi-

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mental plots included similar proportions of the different clones. In the 20×10 ft planting, plots consisted of 6 rows of 16 points, and seed was collected from the central area of 80×120 ft, leaving the outside rows and two points at both ends of each row as 'guards'. In the double-hedge planting, plots consisted of two double rows of 26 points each, seed being collected from an area 20 points long and 120 ft wide, that is extending to midway between adjacent plots on either side. Data from this experiment are quoted as numbers of seed per tree.

Experiment SG

This experiment was sited in a hedge-planted seed garden, containing five clones planted in sequence. Plots consisted of three rows of 33 points and seed was collected from the two inter-row areas, leaving 22 feet at each end as a guard zone. To calculate the seed production per tree, it was assumed that trees in the two outer rows contributed half of their total seed to the plot.

Experiment SP

In this experiment, a monoclone planting, plots consisted of nine rows of 20 points, and seed was collected from the central area of 110×132 ft, leaving two guard rows on either side and four points on the end of each row as guards. The clone was PB 86, a self-fertile prolifically seeding clone, the seed of which is not recommended planting material.

Time of Seed Collection

In Experiments F and SP pre-treatment collections of seed were carried out. In all experiments, after commencement of the fertiliser treatments, frequent collections were made over peak seed-fall periods (the normal time of seed collection) as indicated in *Tables 2, 3* and *4*, while in Experiment SG collections were continued over the greater part of the year in order to obtain data on total annual seed fall. In Experiment F limited records of seed weight and viability were obtained. In this paper only the more important data are discussed, and the bulk of the records are deposited in the *Supplement* (WATSON AND NARAYANAN, 1964).

Leaf Nutrient Content, Girth and Yield Data

Leaf samples for chemical analysis were taken both before and after treatment in Experiments SG and SP, and detailed records of girth and latex yield were also taken in these experiments. The data are referred to briefly below, and will be discussed more fully in subsequent papers.

RESULTS

Experiment F

Frequent collections of seed were made from 1957 to 1963, and statistical analysis was carried out on the bulked weekly collections made over peak seed-fall periods. A similar pattern of results was shown for both the rectangular and hedge systems of planting. No response to either phosphate or potassium chloride application was found, but a significant positive response to ammonium sulphate was evident at most collections. This response was particularly marked in the spring seed-fall collections, and amounted to an overall increase of about 30% in total seed-fall over the seven years of collections; representative data are quoted in *Table 2*.

Experiment SG

Seed collection. Very detailed seed-fall records were obtained in this experiment; no phosphate effect was apparent, but significant depressive effects due to the application of potassium chloride occurred at peak seed-fall periods and also over the total annual seed fall (*Table 3*). No significant nitrogen effects were observed in 1957, 1958 and 1959, but a significant negative effect at the second level of application was recorded in the 1960 peak seed-fall collections. In 1961, 1962 and 1963, a detailed study of the nitrogen effect (see *Supplement*) showed anomalies between peak seed-fall data and that of the annual seed fall: collections taken at the very peak of the seed-fall showed a negative effect due to nitrogen, while on either side of the peak, and generally through the year at lesser rates of seed pro-

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TABLE 3. EXPERIMENT SG. EFFECT OF AMMONIUM SULPHATE AND POTASSIUM CHLORIDE ON SEED PRODUCTION (WEIGHT IN GRAMS PER TREE)

Type of collection	Treatment	1957 19.8–7.10	1958 10.2–15.4	1959 20.7–7.9	1960 15.8–26.9	1961 7.8–23.9	1962 20.8–8.10	1963 21.1–11.3
Peak seed fall	No. of collections	8	8	8	7	8	8	8
	n_0	34.0	126.0	222.1	256.5	790.5	1093.5	498.4
	n_1	29.7	140.7	271.3	258.1	736.0	1138.0	488.5
	n_2	28.6	151.4	257.0	195.3	678.3	1000.8	481.9
	Sig. of n_2-n_0 effect				*	†		
	k_0	27.0	150.3	221.5	280.6	790.2	1176.8	555.3
	k_1	35.6	140.0	289.1	221.3	780.7	1070.6	440.6
	k_2	29.8	127.8	239.9	207.9	633.9	984.8	473.0
	Sig. of k_2-k_0 effect				*	*	†	
	s.e.	±2.83	±21.28	±30.34	±18.44	± 39.72	±72.00	±38.32
	Min. 5% sig. diff.	8.5	64.1	91.4	55.6	119.7	217.0	115.5
Total annual	No. of collections	10	29	27	17	47	46	52
	n_0	50.6	214.8	482.1	476.6	1944.2	1872.0	1000.9
	n_1	43.5	227.5	587.8	493.5	1987.2	2069.6	1061.1
	n_2	39.2	234.1	539.6	414.0	1957.3	1992.4	1076.6
	Sig. of n_2-n_0 effect							
	k_0	37.1	243.0	495.6	581.2	2107.5	2151.4	1237.1
	k_1	52.7	230.9	607.7	439.4	1996.0	1996.2	956.1
	k_2	43.5	202.5	506.2	363.5	1785.2	1786.4	945.5
	Sig. of k_2-k_0 effect				***	†	*	***
	s.e.	±4.72	±32.16	±74.17	±34.40	±114.88	±116.27	±45.65
	Min. 5% sig. diff.	14.2	96.9	223.5	103.7	346.2	350.4	137.6

Effects non-significant except where indicated: ***$P<0.001$, **$P<0.01$, *$P<0.05$ †$P<0.10$.

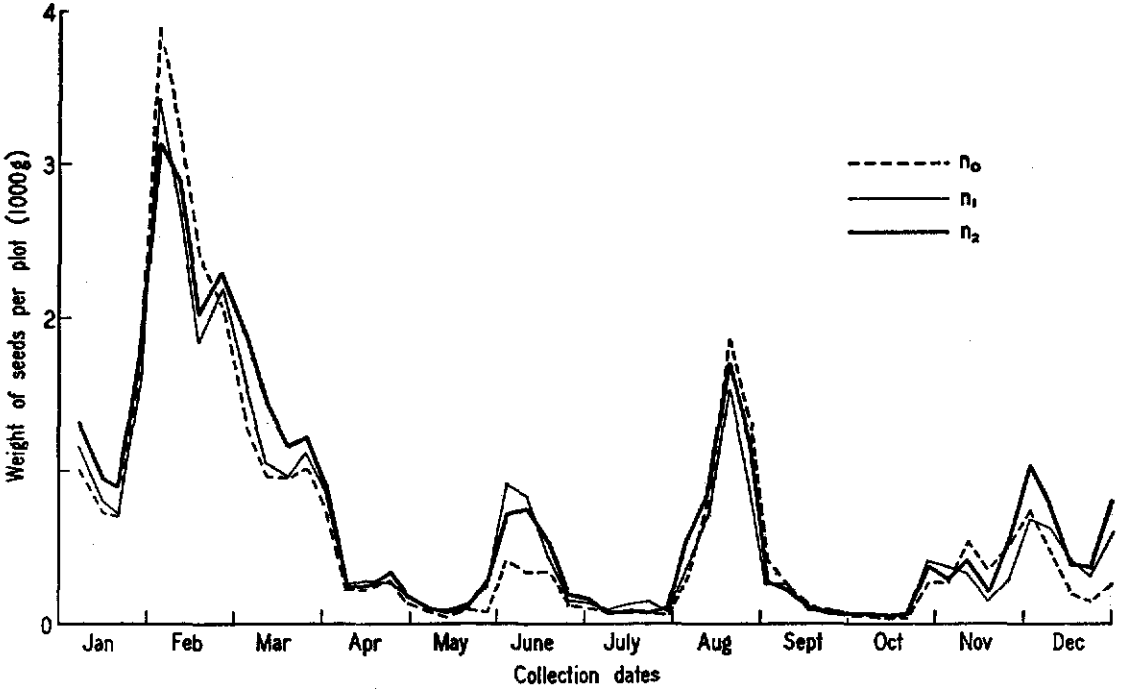

Figure 1. Experiment SG. Effect of ammonium sulphate application on seed production. 1963.

duction, the application of nitrogen increased seed fall. Data for 1963, which typify the anomaly, are illustrated in *Figure 1*. In this year, and in 1961, the change in effect took place at both the spring and autumn seed fall, while in 1962, which experienced a low spring seed fall, the change was only apparent in the autumn. There is no obvious explanation for this effect and very detailed observation would be needed to determine whether it is due to an effect at flowering or at some stage of fruit development. There were slight indications that defoliation and refoliation were earlier on trees that had not received ammonium sulphate (SHORROCKS AND PUSHPARAJAH, 1964) and this may be linked with the pattern of seed production.

Experiment SP

In this experiment, pre-treatment collections of seed made in the autumn of 1958 showed a spurious negative N effect and covariance analysis has been used to correct all post-treatment collection data (see *Supplement*). Two collections were made in the autumn of 1959 but the data showed no effects and are not quoted. The data for peak seed fall and total annual collections in 1960, 1961 and 1962 showed in each year significant positive effects due to the application of ammonium sulphate, the increases in seed fall due to the second level of application being of the order of 80% for the total collections (*Table 4*). In 1961, when two periods of high seed fall were experienced, the response in the spring seed fall was again much greater than that in the autumn seed fall. No consistent effects due to phosphate application or to potassium chloride were recorded.

Seed Weight and Germination Rate

Tests on seed from Experiments F and SG showed that fertiliser had no effect on seed weight. Detailed recordings in Experiment

TABLE 4. EXPERIMENT SP: EFFECT OF AMMONIUM SULPHATE AND POTASSIUM CHLORIDE ON SEED PRODUCTION (WEIGHT IN GRAMS PER TREE)

Treatment	PEAK SEED-FALL COLLECTIONS				TOTAL ANNUAL COLLECTIONS		
	1960 5.11–19.12	1961 21.1–18.2	1961 23.9–20.10	1962 26.10–23.11	1960	1961	1962
No. of collections	4	3	3	3	19	16	7
n_0	137.7	93.2	238.2	171.5	347.5	513.2	320.5
n_1	200.0	188.7	254.6	243.6	540.3	674.3	390.0
n_2	202.9	340.6	347.2	329.8	626.0	956.6	557.8
Sig. of n_2-n_0 effect		***		**	**	**	***
k_0	174.5	201.8	232.3	248.4	545.0	695.2	420.0
k_1	179.0	184.8	233.1	244.6	498.4	616.2	422.7
k_2	186.9	235.7	374.6	251.9	470.4	832.9	425.6
s.e.	±28.62	±32.44	±50.34	±28.55	±46.21	±74.71	±37.15
Min. 5% sig. diff.	86.8	98.4	152.7	86.6	140.2	226.6	112.7

Effects non-significant except where indicated: *** $P < 0.001$, ** $P < 0.01$.

Note: All post-treatment data have been adjusted for significant pre-treatment differences.

TABLE 5. EXPERIMENT F: EFFECT OF AMMONIUM SULPHATE ON PERCENTAGE GERMINATION RATES

(Data quoted are mean germination rates shown by seed collected from all plots and bulked for testing at each time of collection)

Treatment	1959 28.8—29.10	1961 15.8—11.10	1963 9.2—27.4	1963 19.8—15.10
No. of collections	7	9	12	9
n_0	62	72	51	72
n_1	67	75	53	72
n_2	71	79	52	77
Approximate no. of seeds tested per treatment	20,000	43,000	45,000	27,000

F showed that at peak seed-fall periods seed weights ranged between 4.0 and 5.3 g per seed, but at other times fell to below 4.0 g per seed (see *Supplement*). In this experiment there was little variation in germination rates during periods of high germination, but at times when germination was relatively poor, seeds from plots manured with ammonium sulphate proved most viable. Data obtained from germination tests of bulked seed samples, given in *Table 5*, are not conclusive but confirm a tendency for high nitrogen treatments to show the best germination rates.

Leaf Nutrient Status. Experiments SP and SG

In Experiment SP large pre-treatment plot variations in seed fall and in leaf nitrogen and potassium contents were observed and analysis has shown these factors to be significantly correlated (*Figure 2*).

Trees in both experiments were leaf sampled frequently in the course of studies on the effect of fertilisers on leaf nutrient status, and meaned data for samplings in 1961, 1962 and 1963 are given in *Table 6*. Trees in Experiment SG had a higher nitrogen status and lower potassium status than trees in Experiment SP—a difference in accord with previous experience on the two soil types concerned; leaf phosphorus contents were similar in both experiments.

DISCUSSION

The results of the three experiments confirm the preliminary *ad hoc* work, showing that fertiliser application can materially affect seed production. It seems that the supply of nitrogen and potassium is important: in the pre-treatment leaf analytical data for the different plots of Experiment SP, nitrogen contents ranged from 2.64% to 3.42% and potassium contents from 0.92% to 2.08% and were, respectively, positively and negatively correlated with seed fall. Also, at Experiment SP, post-treatment average nitrogen contents ranged from 3.04% at n_0 to 3.35% at n_2, and linear positive responses in seed fall to nitrogen application were recorded; on the other hand at Experiment SG, where nitrogen application had only slight and in-

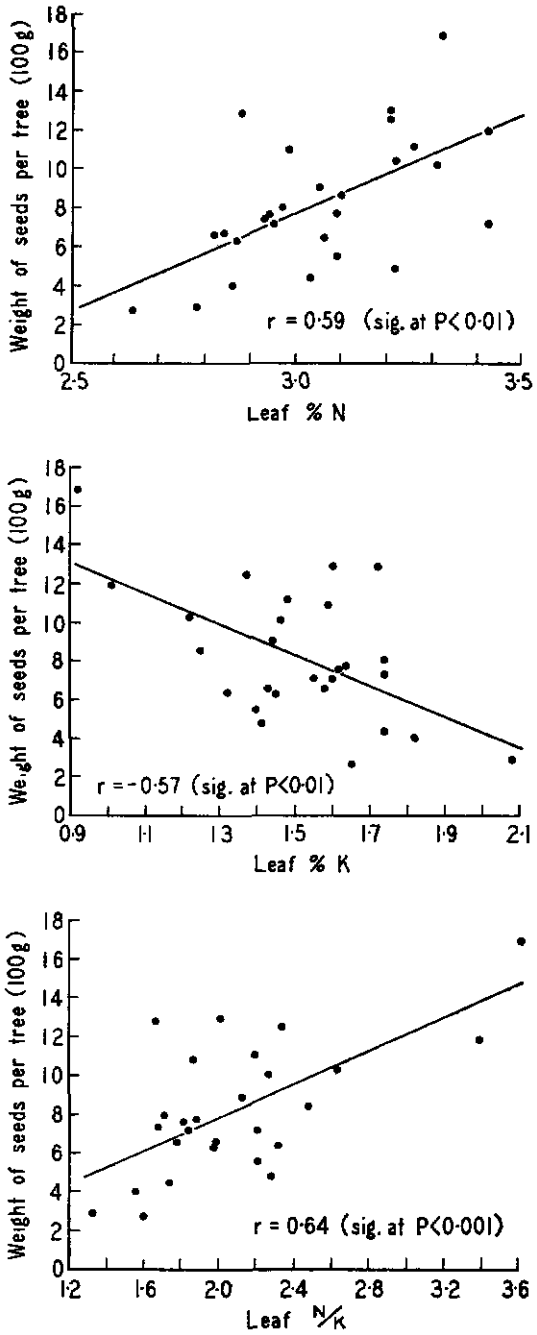

Figure 2. Experiment SP. Relation between leaf nutrient content and seed production (pre-treatment data).

consistent effects on seed fall, the nitrogen contents were higher, in the range 3.33% to 3.51%. It would appear that an appreciable response in seed production to the application of ammonium sulphate is likely to be obtained where the average leaf nitrogen content during the year is below 3.30%.

No leaf analysis was carried out at Experiment F, but the increase in seed production due to ammonium sulphate in that experiment appears to indicate a nitrogen requirement, in accord with other experience when recording tree girth and yield in experiments on the particular coastal alluvial soil concerned (PUSHPARAJAH, 1964).

The relative responses to the application of potassium chloride at Experiments SP and SG are unexpected. In Experiment SG, where levels of leaf potassium would be considered inadequate for satisfactory tree growth and yield (*Table 6*), and where, in fact, positive responses to potassium application in growth and yield are currently being recorded, seed production was linearly depressed: in Experiment SP, however, where leaf potassium contents were much higher, the potassium application had little effect. It would appear that seed production is favoured by low levels of potassium in the leaf.

A study of the relative effects of nitrogen and potassium fertilisers on seed fall indicates that seed production will be favoured by a widening of the N/K ratio in the leaves, and this is confirmed by the pre-treatment data from Experiment SP, where the N/K ratio shows a higher correlation with seed fall than does either the leaf nitrogen or potassium content on its own (*Figure 2*).

No response was obtained to the application of rock phosphate, but this is not surprising in view of the satisfactory leaf phosphorus contents (RUBBER RESEARCH INSTI-

TABLE 6. EXPERIMENTS SG AND SP: LEAF NUTRIENT CONTENT

(Data given as average percentages determined on low leaves — shade (SHORROCKS, 1962) with mid-ribs. For information on effects of sampling time refer to SHORROCKS, 1965. Number of samples† in parenthesis).

Treatment		SG 1961 (1)	SG 1962 (8)	SG 1963 (6)	SP 1961 (2)	SP 1962 (3)	SP 1963 (2)
% N	n_0		3.33			3.04	
	n_1		3.47			3.25	
	n_2		3.51			3.35	
	s.e.		±0.037			±0.077	
% P	p_0		0.24			0.23	
	p_1		0.26			0.25	
	p_2		0.28			0.25	
	s.e.		±0.005			±0.007	
% K	k_0		0.88			1.85	
	k_1		1.16			1.87	
	k_2		1.28			1.96	
	s.e.		±0.028			±0.048	

† Months of sampling	1961	1962	1963
Experiment SG	Nov.	Jan., April, May, June, Aug. Sept., Oct., Dec.	May, Aug., Sept., Oct., Nov., Dec.
Experiment SP	June, Dec.	May, Aug., Nov.	July, Nov.

TUTE OF MALAYA, 1963b). The generally beneficial effects of phosphate application reported in the introduction to this paper, which must have been obtained under conditions of phosphate deficiency, cannot therefore be confirmed, but the results indicate that in the presence of a satisfactory supply of phosphate, maximum seed production can be ensured by maintaining a wide N/K leaf ratio. This could be achieved by the use of nitrogenous fertilisers which would both raise the nitrogen status of the tree and also tend to depress that of potassium (SHORROCKS, 1961). On soils with a high potassium content, potassic fertilisers could be usefully dispensed with, but this action would only be possible on low-potassium soils at the expense of reduced growth and yield.

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Soils Division
Rubber Research Institute of Malaya
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