FERTILIZER RESPONSES OF TEA IN THE UP-COUNTRY DISTRICTS

V. P. Bhavanandan & W. B. Manipura.

This paper reviews the results of fertilizer experiments now in progress at St Coombs and other estates in the up-country districts. Results available to-date show that the yield response of tea to nitrogen in these experiments is limited. Although seedling tea in these districts responded to levels of nitrogen up to 360 lb per acre per year, it was seen that the overall return above 240 lb nitrogen was in most instances less than 2 lb of made tea per pound of nitrogen. Clonal tea, however, showed highly significant and economic responses up to 300 lb nitrogen per acre per year, which was the highest level tested.

Yield responses of both seedling and clonal teas to phosphate and potash were very minimal. In many experiments, no response to phosphate or potash was obtained. Seedling tea showed yield responses to 30 lb P_2O_5 and 100 lb K_2O only in the oldest experiment, where zero phosphate and potash levels had been maintained for 37 years. In the case of clonal tea, yield response to potash was obtained only up to 62.5 lb K_2O.

Looking at the trends of the results from the various fertilizer experiments in the different tea-growing districts it is felt that the time is now opportune to revise the existing fertilizer recommendations for tea in Ceylon. In order to do this it is necessary firstly to review the available results of the fertilizer experiments in the four major tea-growing regions of Ceylon, namely the up-country, low-country, mid-country and Uva. The results from one of the important fertilizer experiments on low-grown clonal tea has already been published (Fernando, Bandaranayake & Yogaratnam 1969). This paper reviews the results of the more important fertilizer experiments carried out in the up-country districts. The results from the experiments in the mid-country and Uva districts will be published in due course. The new fertilizer recommendations incorporating the recent results from all the districts are presented in a separate paper (Fernando, Bhavanandan, Wettasinghe & Manipura 1969).

Experimental

Experiment A1

This experiment, designed to test three levels each of nitrogen, phosphate and potash, was started by Dr Eden in No. 3 Field of St Coombs, in 1931. The tea in this experiment is now in its 12th pruning cycle. Details regarding the treatments and results of the earlier cycles up to the tenth have been published previously (Eden 1949; Tolhurst 1964; Annual Reports of the Agricultural Chemistry Division 1958-1967).

The levels of the three nutrients, N, P and K, had been increased whenever a trend was noticed towards yield increase at the then existing levels. However, the zero phosphate and zero potash treatments had been maintained throughout. The levels of the nutrients tested and the results obtained during the last completed cycle (eleventh) are given in Table 1.

TABLE 1—*Yield of made tea for the 54 months of the 11th cycle—Experiment* **A1**, *St Coombs*

Nutrient	Rate of application (lb/acre/year)	Yield (lb/acre)
Nitrogen	120	2793
	150	3165
	180	3645
Phosphate	0	2796
	30	3478
	60	3333
Potash	0	1887
	50	3713
	100	4008
LSD	($P<0.05$)	252
	($P<0.01$)	340
	($P<0.001$)	450

As seen from Table 1, the yield responses to nitrogen and potash are significant and linear up to 180 lb and 100 lb respectively, whereas phosphate shows a response only up to the first level (30 lb) and then a slight depression in yield at the highest level, though not significant statistically. There was a highly significant positive interaction between N and K, (Table 2) showing that the response to K increased with increasing levels of N.

TABLE 2—*Interaction of N and K in the 11th cycle—Experiment* **A1**, *St Coombs*

Potash (lb/acre/year)	Nitrogen (lb/acre/year) 120	150	180
0	1884	1714	2061
50	3136	3777	4227
100	3362	4002	4661

Because of the yield responses obtained to N and K, the levels of these nutrients were increased for the 12th cycle ; the new levels and the yields obtained during the first and second years of the 12th cycle are given in Table 3.

TABLE 3 — *Yield of made tea for the first and second years of the 12th cycle — Experiment* **A1** *St Coombs*

Nutrient	Rate of application (lb/acre/year)	First Year (lb/acre)	Second year (lb/acre)
Nitrogen	120	697	942
	180	688	1029
	240	728	1126
Phosphate	0	575	889
	30	798	1134
	60	740	1075
Potash	0	382	542
	75	884	1273
	150	847	1283
LSD	($P < 0.05$)	85	112
	($P < 0.01$)	115	152
	($P < 0.001$)	153	201

The response to nitrogen in the 1st and 2nd years is not statistically significant. There is a highly significant response to 30 lb P_2O_5 per acre per year, but there is no further increase in yield for an additional 30 lb P_2O_5. In fact, the depression in yield at the highest level of P_2O_5 noticed in the 11th cycle is still evident. For potash there is a highly significant response in both years to 75 lb K_2O per acre per year, but there is no further increase above this level.

Experiment A2

This experiment, designed to test 3 levels of nitrogen (75, 150 and 225 lb per acre per year), 3 levels of zinc sulphate (0, 10 and 20 lb per acre per year) and three frequencies of zinc sulphate spraying (2, 4 and 6 applications per year), was initiated in No. 9 Field at St Coombs in 1962. Potash was applied to all plots at the rate of 30 lb K_2O per year, but no phosphate or magnesium was given. The yield responses to nitrogen were very highly significant (Table 4).

TABLE 4 — *Yield of made tea in pounds per acre for the first two years — Experiment* A2, *St Coombs*

Treatment	Rate of application (lb/acre/year)	Yield (lb/acre)
Nitrogen	75	2175
	150	2609
	225	3038
Zinc sulphate	0	2521
	10	2614
	20	2708
	LSD ($P < 0.05$)	171
	($P < 0.01$)	231
	($P < 0.001$)	308

A significant increase in yield was obtained from the application of 20 lb zinc sulphate per acre per year. The frequencies of application of zinc sulphate did not show significant differences in yield.

For the third year, which was the last year of the cycle, the nitrogen levels were increased to 100, 200 and 300 lb, but the zinc sulphate levels were unchanged ; the third factor was changed from frequency of zinc sulphate applications to levels of phosphate (0, 25 and 75 lb P_2O_5 per acre per year). Potash was increased from 30 to 90 lb K_2O per acre per year. During this year a very highly significant linear response was obtained for the levels of nitrogen as shown below.

N1(100)	N2(200)	N3(300)
1270	1403	2085
LSD ($P < 0.001$)	219	

Increasing the nitrogen from 200 to 300 lb gave an increase of 680 lb made tea, which is a return of 6.8 lb made tea per pound of nitrogen. There was no response to phosphate or zinc sulphate during this period.

In the second cycle, the nitrogen levels were again increased to 150, 300 and 450 lb N per acre per annum, while the phosphate and zinc sulphate levels were unchanged. Liming treatments were introduced by splitting each plot into two sub-plots ; one sub-plot received no Limbux, while the other was given Limbux at the rate of one ton per acre, in one replicate. In the other replicate, one sub-plot received no Limbux while the other received Limbux at the rate of two tons per acre. The aim of this treatment is to alter the pH, in the upper profile of the soil. The results of the first 24 months of this cycle are given in Table 5. The replicates are considered separately because of the differential lime treatments.

TABLE 5 — *Yield response for the first 24 months of the second cycle — Experiment A2, St Coombs*

Nutrient	Rate of application (lb/acre/year)	Yield (lb/acre for 24 months) Replicate 1	Replicate 2
Nitrogen	150	2767	2771
	300	2998	3002
	450	2980	3052
Zinc sulphate	0	2813	2759
	10	2828	2894
	20	3094	3172
	LSD ($P < 0.05$)	168	177

There is a significant response in yield up to 300 lb nitrogen in both replicates. As in the 1st cycle there is a yield response to 20 lb zinc sulphate per acre per year, but there is no yield response to phosphate or the lime treatments. It is interesting to note that no significant response to phosphate was obtained in this experiment even though phosphate was not applied to this experimental area for the first two years and from the third year of the experiment one treatment was zero phosphate.

Experiment A12

This experiment on high jat tea situated in No. 3 Field of St Coombs was laid out in 1966. The factors studied were five levels of nitrogen (90, 180, 270, 360 and 450 lb per acre per year), two levels of phosphate (0 and 30 lb per acre per year) and three levels of potash (0, 75 and 150 lb per acre per year). The first cycle ended after 27 months of experimental plucking. The yield for the different nitrogen levels expressed as pounds per acre per year, the yield increments in pounds and the return of made tea per pound of nitrogen are given in Table 6.

TABLE 6 — *Response to nitrogen for 27 months of the first cycle — Experiment* A12, *St Coombs*

Nitrogen (lb/acre/year)	Yield (lb/acre/year)	Yield increment (lb)	Return (lb made tea/lb N)
90	1031	—	—
180	1434	403	4.5
270	1756	322	3.6
360	1950	194	2.2
450	2083	133	1.5
LSD ($P < 0.05$)	230		

The response to nitrogen is significantly quadratic, showing that the response was gradually declining within the range of levels tested. There is no response to phosphate in this experiment, to-date. A significant response to potash is evident only between the lowest and highest levels (see below).

Potash (lb/acre/year)	Yield (lb/acre/year)
0	1592
75	1648
150	1719
LSD ($P < 0.05$)	99

Experiment A8

This is the first fertilizer experiment on high-grown clonal tea (TRI 2024). This experiment, designed to test three levels each of nitrogen, phosphate and potash, was planted out in No. 8 Field of St Coombs in 1962. The experiment consists of six blocks of ten plots each, one plot in each being allocated at random to receive no fertilizer. The treatments in this experiment were applied from the time of planting. The levels of nutrients applied in the last two years of the five-year cycle are given in Table 7. For statistical analysis, the experiment is treated in two groups because of marked differences between the yields of the replicates. Group 1 comprises the three better replicates and Group 2 the three poorer replicates. The blocks in Group 1 are situated on gently sloping land and the soil appears to be free of gravel, while the blocks in Group 2 are situated on steep, gravelly soil. In addition, the blocks in the poorer group were found to have a higher infestation of nematodes.

The results of the three plucking years of the first cycle are summarized in Table 7.

TABLE 7 — *Yield response to N, P and K for the three years of the first cycle—Experiment* **A8**, *St Coombs*

Treatment	Rates of application (lb/acre/year)	Yield Group 1 (lb/acre)	Yield Group 2 (lb/acre)
Nitrogen	100	5810	3211
	200	7286	4953
	300	8597	5417
Phosphate	0	7418	4701
	50	6994	4892
	100	7280	3989
Potash	0	7023	3720
	62.5	7536	4809
	125	7134	5052
Mean of control plots		2926	1264
LSD ($P < 0.05$)		431	974
($P < 0.01$)		554	1476

The tea in Group 1 showed a highly significant yield response up to the highest level of nitrogen (300 lb) applied, whereas in Group 2 the response from 100 to 200 lb N was very much higher than the response from 200 to 300 lb N. There was no response to phosphate in either group. In the case of potash, a significant response to 62.5 lb K_2O is evident in both groups. In the poorer group, there was no further significant change on increasing potash to 125 lb, but in the better group there was a depression in yield, which just failed to reach significance at the 5% level of probability. Further, in the better group, the overall return on increasing the nitrogen from 100 to 300 lb is 4.5 lb of made tea per pound nitrogen per year, whereas for the poorer group, the figure was 3.7 lb.

The levels of nutrients being tested are unehanged for the 2nd cycle. The results for the first year of the second cycle is presented in Table 8.

TABLE 8 — *Yield response to N, P and K during the 1st year of the 2nd cycle—Experiment* **A8**, *St Coombs*

Treatments	Rates of application (lb/acre/year)	Yield (lb/acre/year) Group 1	Group 2
Nitrogen	100	1251	953
	200	1413	1221
	300	1406	1089
Phosphate	0	1387	1141
	50	1320	1148
	100	1361	975
Potash	0	1364	1052
	62.5	1394	1061
	125	1312	1150
Mean for control plots		638	448
LSD ($P < 0.05$)		58	165

It is seen that in both groups, the yield response to 200 lb N is significant; in Group 1 there is no further increase on increasing the N to 300 lb, while in Group 2 there is a depression of yield at 300 lb N. There was no response to phosphate and potash in either group.

Extension Experiments

Sixteen extension experiments investigating responses to fertilizer were started in 1965 on various estates in the up-country (Tolhurst 1966a). The details of treatments and the designs of these experiments have been published in the Annual Reports of the Agricultural Chemist (Tolhurst 1966b, 1967 and 1968). The common treatments in these experiments were three types of nitrogenous fertilizer, namely sulphate of ammonia (SA), urea and calcium ammonium nitrate (CAN), each at three levels. Seven experiments had three levels of potash as the third factor and five experiments had three levels of Limbux as the third factor.

The results from these experiments are now available for periods varying from 12 to 28 months. Table 9 summarizes the yield responses to nitrogen obtained in these experiments. Eleven out of the 16 experiments show statistically significant yield responses to the levels of nitrogen tested. In 12 out of the 16 experiments there are no yield differences between the types of nitrogen, *viz* SA, urea and CAN. In two experiments SA gave better yields than urea and CAN ; in one experiment urea and CAN are both faring better than SA, and in another experiment SA and urea are better than CAN. None of the seven experiments testing three levels of potash is showing any yield response to this nutrient. Also in the five experiments testing three levels of Limbux no yield response was obtained.

Discussion

Response to nitrogen

Yield responses to nitrogen have been obtained over a wide range of nitrogen levels and among other factors the type of tea under consideration appears to be important. In Experiment A1 where the tea is of a mixed low jat and generally low-yielding, significant yield responses up to 180 lb N were obtained in the 11th cycle. The return per pound of nitrogen from 120 to 150 lb was 2.7 lb made tea, and from 150 to 180 lb, 3.5 lb made tea. Yield response to increased levels of nitrogen dropped markedly in the 1st and 2nd years of the 12th cycle and was not statistically significant. In Experiment A2 where the tea is of a high jat type and the yield levels are high, marked responses up to 225 lb N were obtained in the first two years of the 1st cycle. The overall return was of the order of 5.7 lb made tea per pound of nitrogen in the first two years, out of which 4.5 lb was obtained in the 2nd year. In the last year of the first experimental cycle when the levels of nitrogen were increased to 100, 200 and 300 lb, again, there was response up to the highest level. The overall return of 4.1 lb made tea per pound of nitrogen was still high. In the 2nd cycle when the levels of nitrogen were once again raised to 150, 300 and 450 lb responses were obtained only up to 300 lb, but the return per pound of nitrogen over the range 150 to 300 had dropped to 0.75 lb made tea. Thus it is seen that even though there were marked responses in the 1st cycle when the nitrogen levels were low, the responses gradually declined and presently in the 2nd cycle 150 lb N seems to be giving the most economical yield. In Experiment A12 where a wider range of

TABLE 9 — *Yield responses to nitrogen in the Extension Experiments*

Experiment	Estate	Nitrogen levels and yield (lb/acre/year)			LSD ($P < 0.05$)	Return (lb tea/lb N) 1st Increment	Return (lb tea/lb N) 2nd Increment
XA1	Tangakelle	120	240	360			
		1866	2129	2314	283	2.2	1.5
XA2	Mayfield	120	240	360			
		1867	2498	2647	114	5.3	1.2
XA3	Hauteville	120	240	360			
		878	911	974	NS	0.3	0.5
XA4	Diyagama East	120	240	360			
		3105	3197	3357	130	0.8	1.3
XA5	Ederapolla	120	240	360			
		3133	3134	3191	NS	0.0	0.5
XA6	Blairlomond	120	240	360			
		2116	2154	2338	NS	0.3	1.5
XA7	Kirkoswald	120	240	360			
		1921	2223	2439	214	2.5	1.8
XA8	Brunswick	120	240	360			
		2161	2635	2996	105	4.0	3.0
XA9	Holyrood	120	240	360			
		732	719	753	NS	—0.1	0.3
XA10	Clarendon	90	180	270			
		1561	1559	1738	NS	0.0	2.0
XA13	Ottery	90	180	270			
		2130	2242	2417	134	1.2	1.9
XA14	Dickoya	90	180	270			
		1320	1565	1724	70	2.7	1.8
XA15	Kotiyagala	90	180	270			
		1830	2048	2301	262	2.4	2.8
XA16	Oonagaloya	90	180	270			
		1856	1954	2100	65	1.1	1.6
XA17	Diyagama East	90	180	270			
		2334	2511	2844	131	2.0	3.7
XA18	Gonapitiya	90	180	270			
		2701	2893	3059	248	2.1	1.8

nitrogen was tested the responses were significant only up to 270 lb; above this level, the responses are small and statistically not significant. The yield return per pound of nitrogen was 4.5 lb made tea over the range 90 to 180 lb, but this dropped gradually with increasing levels of nitrogen and was only 1.5 lb made tea per pound of nitrogen in the range 360 to 450 lb (Table 6).

In the extension experiments the responses to nitrogen varied (see Table 9). Five (**XA3, XA5, XA6, XA9** and **XA10**) of the 16 experiments, showed no responses to nitrogen. In the remaining 11 experiments statistically significant yield responses were obtained, but in three (**XA4, XA13** and **XA16**) the returns were below 2 lb made tea per pound nitrogen in both ranges, and in five (**XA1, XA2, XA7, XA14** and **XA18**) the return of made tea per pound nitrogen was above 2 lb only up to the

intermediate level (180 or 240 lb). In the remaining three (XA8, XA15 and XA17) the returns were above 2 lb made tea up to the highest level of nitrogen tested, namely 270 or 360 lb. Therefore, out of the 16 extension experiments, the results so far obtained show that in eight experiments there were no economical responses above 90 or 120 lb N, while in five the yield responses were economical up to 180 or 240 lb, and in three, up to the highest level tested (270 or 360 lb).

Thus, summarizing, it could be said that on the whole the responses to nitrogen of mature seedling tea in the up-country appear to be best in the region of 90 to 240 lb, although occasionally responses up to 270 and 360 lb are obtainable. In regard to clonal tea in the up-country, in the only experiment carried out, highly significant responses and returns in the region of 4 lb made tea per pound nitrogen were obtained up to the highest level (300 lb) tested.

Responses to phosphate

Of the three experiments in which the responses of mature tea to phosphate were tested, only one experiment showed significant responses to 30 lb P_2O_5 per acre per year. In this experiment the first level of phosphate, which was zero, was maintained for about 37 years. In Experiments A2 and A12, where the zero phosphate plots had not received phosphate for six years and three years respectively, there was no response to this nutrient. This is in agreement with previous findings (Tolhurst 1963).

In Experiment A8 where the response of clonal tea to phosphate was tested, no response to this nutrient had yet been obtained even though the zero phosphate plots did not receive any phosphate since the time of planting, which was in 1962.

Responses to potash

In the oldest experiment (A1), there was a significant response up to 100 lb K_2O in the 11th cycle. In the 12th cycle, when the levels of K_2O were increased from 0, 50 and 100 lb to 0, 75 and 150 lb the response was only up to 75 lb. Again, the zero level had been maintained for about 37 years. In Experiment A12 where the response of high jat tea to potash was tested, a statistically significant difference was obtained only between the lowest and highest levels. In the seven extension experiments testing responses to potash, so far none has given a response to this nutrient. In conclusion, it can be said that the responses to potash of mature seedling tea is minimal. However, these experiments are of only a few years' duration and it is possible that responses to potash might occur at a later stage. Experiment A1 which showed highly significant responses to 100 lb K_2O in the 11th cycle, first responded to this nutrient only after 12 years of zero potash treatment (Eden 1949).

In the case of clonal tea yield responses to potash were obtained only up to 62.5 lb K_2O.

Acknowledgements

The authors wish to express their gratitude to Mr J. A. H. Tolhurst and Dr H. N. Hasselo, who were responsible for planning and laying down many of the field trials reported in this paper. We wish to acknowledge the assistance given by the research and technical staff of the Agricultural Chemistry Division in carrying out the field trials. We are thankful to the Statistician and his assistant for the analyses of the data and to the Superintendents of estates on which extension experiments were carried out for their co-operation.

References

EDEN, T. (1949). The work of the Agricultural Chemistry Department of the Institute. *Monograph on Tea Production in Ceylon,* **No. 1.** Talawakele, Tea Research Institute of Ceylon, 78 pp.

FERNANDO, L. H. BANDARANAYAKE, J. I. H. & YOGARATNAM, N. (1969). Fertilizer responses in low-grown clonal tea. *Tea. Q.* **40,** 53-59.

FERNANDO, L. H., BHAVANANDAN, V. P., WETTASINGHE, D. T. & MANIPURA, W. B. (1969). Fertilizer recommendations for tea in Ceylon — 1969. *Tea Q.* **40,** .

TOLHURST, J. A. H. (1963). Concluding report on a phosphate manurial trial, St Goombs. *Tea Q.* **34,** 144-147.

TOLHURST, J. A. H. (1964). Observations on the progress of certain manurial trials on St Coombs. *Tea Q.* **35,** 57-60.

TOLHURST, J. A. H. (1966a). Extension experiments. *Tea Q.* **37,** 47-50.

TOLHURST, J. A. H. (1966b). Report of the Agricultural Chemistry Division, *Rep. Tea Res. Inst. Ceylon* (1965) **2,** 18-26.

TOLHURST, J. A. H. (1967). Report of the Agricultural Chemistry Division. *Rep. Tea Res. Inst. Ceylon* (1966) **2,** 24-38.

TOLHURST, J. A. H. (1968). Report of the Agricultural Chemistry Division. *Rep. Tea Res. Inst. Ceylon* (1967) **2,** 25-41.