Investigations on the Cultivation of Citronella in Ceylon

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I.—The Effects of Organic and Artificial Fertilizers on the Yield of Grass and Oil

INVESTIGATIONS on factors that can contribute to the improvement of citronella yields in Ceylon commenced at Mapalana in the Matara District in 1939. The effects of organic manure and artificial fertilizers on the yield of grass and oil were studied over a period of six years with *Cymbopogon winterianus* Jowitt, locally named *Mahapangiri*, and *Cymbopogon nardus* Rendle known as *Lenabatu-pangiri*. Of the two species *Cymbopogon nardus* is more commonly cultivated in Ceylon.

Material and Methods

Planting material of the two species was obtained from the Agricultural Station, Labuduwa, Galle, where these had been grown separate for a few years. Planting was done in the *maha* (north-east monsoon) season of 1939, between the twelfth and twenty-third of October. The land was ploughed and harrowed in the usual way. No application of organic manure or artificial fertilizer was made. The land was gently undulating and the soil was a typical lateritic gravelly loam.

Four blocks, each measuring 30 feet by 144 feet, were demarcated. Each block accommodated six plots; the plot dimensions were 30 feet by 24 feet. The long side of each plot was in

Table 1—Monthly Rainfall in Inches at Mapalana during the Period 1939 to 1945

	1939	*1940*	*1941*	*1942*	*1943*	*1944*	*1945*
January	1·46	0·79	1·52	5·69	1·98	5·52	0·40
February	1·22	1·20	1·31	1·44	2·48	10·11	0·69
March	1·46	5·67	2·88	6·50	7·50	6·67	11·29
April	14·77	3·47	8·10	18·67	4·95	7·66	5·84
May	11·51	18·07	17·04	11·40	23·89	25·22	5·32
June	6·62	9·16	8·46	9·71	8·72	7·46	11·11
July	3·41	2·17	8·47	5·31	2·75	3·43	5·24
August	7·89	8·13	8·86	5·17	3·77	6·33	2·67
September	5·10	4·96	16·65	7·07	1·54	10·89	4·60
October	13·46	12·16	13·46	18·14	7·70	15·37	11·50
November	12·67	13·61	13·78	6·84	14·98	14·05	12·97
December	8·91	9·49	0·52	13·35	7·46	5·37	1·79
Total	88·48	88·88	101·05	109·29	87·72	118·08	73·42

the direction of the fertility gradient, viz., along the slope of the land. The three fertilizer treatments, combined with the two varieties, gave six treatments in all, which were randomly assigned to the six plots in each block. The design of the experiment was therefore a randomised block with four replicates. The varieties were planted in their respective plots at a spacing of two feet by two feet, in *quincunx* fashion, with three shoots per hill. The rainfall distribution (Table 1) was favourable at the time of planting, with 13.5 inches in October, 12.7 in November, and 8.9 in December. A period of drought followed in January and February. Vacancies occurred and these were supplied in June, 1940. *Cymbopogon confertiflorus* Stapf. (*Mana*) was observed as an impurity in the plots in December, 1940; these rogue plants were removed and vacancies supplied.

Harvests

The first harvest was made on June 26, 1940, that is, eight months after planting. All plots were cut and the fresh weight of grass in each plot was determined. A border of two feet was discarded around each plot and yield records were confined to a plot size of 26 feet by 20 feet.

Harvests were repeated at intervals of three months; the annual yield of each plot was the total of four harvests. Comparisons between treatments were accordingly made on aggregate values of harvests over a complete year, except in the instance of the first harvest, which measured the yield over the first eight months from the date of planting.

Manuring

Manuring commenced immediately after the fifth harvest in June, 1941, and was repeated after every harvest for four successive years. The treatments were—

(1) No manure.
(2) Nitrogen alone.
(3) Nitrogen, phosphate, and potash.

These were supplied as follows:—

(1) No manure (control).
(2) 168 lb. Calcium cyanamide (32 lb. N) per acre per year.
(3) 168 lb. Calcium cyanamide (32 lb. N), 127 lb. basic slag (24 lb. P_2O_5), and 42 lb. muriate of potash (21 lb. K_2O), per acre per year.

In the second year of manuring, commencing June, 1942, groundnut cake was substituted for calcium cyanamide, and saphos phosphate for basic slag, owing to the unavailability of these fertilizers. The quantities of nitrogen and phosphoric acid per acre were maintained, and accordingly the plots received the following treatments:—

(1) No manure.
(2) 504 lb. groundnut cake (35 lb. N) per acre.
(3) 504 lb. groundnut cake (35 lb. N), 84 lb. saphos phosphate (25 lb. P_2O_5), and 42 lb. muriate of potash (21 lb. K_2O), per acre per year.

In the third and fourth years of manuring, a further change in the manurial treatments was considered desirable, and compost with citronella ash was used in

treatment (2). In treatment (3) the quantity of nitrogen was reduced and potash increased. The three treatments were then:

(1) no manure;
(2) 3 tons compost (33 lb. N; 13 lb. P_2O_5; 20 lb. K_2O) per acre with 3 cwt. citronella ash (24 lb. K_2O) per acre;
(3) 336 lb. groundnut cake (24 lb. N), 84 lb. saphos phosphate (25 lb. P_2O_5), and 84 lb. muriate of potash (42 lb. K_2O) per acre per year.

The treatments specified above were applied to the same plots throughout, following the original randomisation of treatments in each block. The total quantity of fertilizer per acre was divided into four equal doses and applied after each harvest.

Results

The yields of *Mahapangiri* and *Lenabatu* and the response to fertilizer applications were determined in terms of weight of grass and of oil. The yield figures of fresh weight of grass are considered first, and are presented in Table 2. Each of the six treatment yields in a block is the total of four harvests in each year; in the first eight months, however, only one harvest was made. Block totals and treatment totals of each year are shown in the table. Separate analyses of variance were done for each of the six years' data and these are presented in Tables 3—8. A summary of yields accompanies each analysis of variance table.

It will be observed that no fertilizers were applied in the first two years, and treatment differences are accordingly only in respect of the two species of citronella, which are hereafter referred to as varieties for convenience. The analyses of variance of the first and second year were done on eight values. Each value is the variety total of three plots in each block. In each of these two years, *Lenabatu* gave a slightly higher yield over *Mahapangiri*, but the difference in yield between these two varieties did not reach the five per cent. level of significance (Tables 3 and 4).

With the application of fertilizers at the end of the second year, there was a striking increase in yield in plots treated with the complete mixture of nitrogen, phosphate, and potash. Plots treated with nitrogen alone gave yields equal to those with no fertilizer. The analysis of variance given in Table 5 shows fertilizer treatments differing significantly at the 0.1 per cent. point of probability. The yield obtained with the complete mixture of NPK was nearly twice that of plots with nitrogen alone.

The results of the fourth year, that is, the second year of manuring, were similar to those of the previous year (Table 6). Fertilizer treatments differed significantly at the 0.1 per cent. point. The NPK plots gave twice the yield of the nitrogen plots. The nitrogen plots gave a yield slightly higher than those of the unmanured control, but again the difference between these was not significant.

In the absence of a response to nitrogen alone, this fertilizer treatment was replaced by compost with citronella ash in the fifth and sixth years. The results of the fifth and sixth years are presented in Tables 7 and 8. Significance at the 0.1 per cent. point was obtained for fertilizer treatments as a whole in each of these years. Plots with the complete NPK mixture of artificial fertilizers significantly outyielded those with compost and ash by fifty per cent. in each of the years. The two fertilizer treatments were significantly superior to the unmanured control.

Table 2—Grass Yields indicating Response of Mahapangiri and Lenabatu to Fertilizers

(Yields are expressed in pounds per plot (26′ × 20′) which is the total of four harvests in each year, except in the instance of the eight months ending June, 1940)

		First Eight Months ending June, 1940 (no fertilizers applied)					*Second Year ending June, 1941 (no fertilizers applied)*					*Third Year ending June, 1942*				
		Blocks					*Blocks*					*Blocks*				
		I	*II*	*III*	*IV*	*Totals*	*I*	*II*	*III*	*IV*	*Totals*	*I*	*II*	*III*	*IV*	*Totals*
MAHAPANGIRI																
Fertilizer treatments	1	100	103	65	54	322	298	228	237	238	1,001	205	213	137	189	744
	2	130	60	85	53	328	358	200	208	216	982	256	186	138	204	784
	3	40	72	136	101	349	256	172	245	270	943	342	317	285	366	1,310
	Totals	270	235	286	208	999	912	600	690	724	2,926	803	716	560	759	2,838
LENABATU																
Fertilizer treatments	1	33	110	112	40	295	286	282	218	229	1,015	150	244	155	167	716
	2	66	195	96	29	386	226	368	211	181	986	161	260	143	155	719
	3	109	54	176	84	423	319	231	310	255	1,115	406	352	257	361	1,376
	Totals	208	359	384	153	1,104	831	881	739	665	3,116	717	856	555	683	2,811
Block Totals		478	594	670	361	2,103	1,743	1,481	1,429	1,389	6,042	1,520	1,572	1,115	1,442	5,649

		Fourth Year ending June, 1943					*Fifth Year ending June, 1944*					*Sixth Year ending June, 1945*					*Total Yield for Six Years*
		Blocks					*Blocks*					*Blocks*					
		I	*II*	*III*	*IV*	*Totals*	*I*	*II*	*III*	*IV*	*Totals*	*I*	*II*	*III*	*IV*	*Totals*	
MAHAPANGIRI																	
Fertilizer treatments	1	214	193	144	142	693	130	120	82	93	425	75	63	53	65	256	3,441
	2	311	188	147	198	844	270	184	151	174	779	183	111	112	116	522	4,239
	3	441	484	418	489	1,832	306	275	275	334	1,190	239	190	221	217	867	6,491
Totals		966	865	709	829	3,369	706	579	508	601	2,394	497	364	386	398	1,645	14,171
LENABATU																	
Fertilizer treatments	1	135	242	136	145	658	99	165	117	104	485	78	97	86	88	349	3,518
	2	155	350	158	174	837	170	253	244	162	829	124	165	175	104	568	4,325
	3	441	397	386	330	1,554	402	264	253	301	1,220	327	189	194	189	899	6,587
Totals		731	989	680	649	3,049	671	682	614	567	2,534	529	451	455	381	1,816	14,430
Block Totals		1,697	1,854	1,389	1,478	6,418	1,377	1,261	1,122	1,168	4,928	1,026	815	841	779	3,461	28,601

Table 3—Analysis of Variance and Summary of Yields of the First Eight Months ending June, 1940

	Degrees of Freedom	*Sum of Squares*	*Mean Square*	*Variance Ratio*	*F. value for Significance (5% point)*
Varieties	1	1,378	1,378	0·28	10·13
Blocks	3	27,445	9,148		
Error	3	14,546	4,848		
Total	7	43,369			

Difference between varieties is not significant.

Variety	*Yield of grass in pounds per acre*
Mahapangiri	6,973
Lenabatu	7,706

Table 4—Analysis of Variance and Summary of Yields of the Second Year ending June, 1941

	Degrees of Freedom	*Sum of Squares*	*Mean Square*	*Variance Ratio*	*F. value for Significance (5% point)*
Varieties	1	4,512	4,512	0·32	10·13
Blocks	3	38,165	12,722		
Error	3	41,190	13,730		
Total	7	83,867			

Difference between varieties is not significant.

Variety	*Yield of grass in pounds per acre*
Mahapangiri	20,423
Lenabatu	21,750

Table 5—Analysis of Variance and Summary of Yields of the Third Year ending June, 1942

	Degrees of Freedom	*Sum of Squares*	*Mean Square*	*Variance Ratio*	*F. value for Significance (0·1% point)*
Varieties	1	31	31		
Fertilizers	2	121,018	60,509	46·62 ***	11·34
Variety × Fertilizer	2	1,139	569		
Blocks	3	21,063	7,021		
Error	15	19,481	1,298		
Total	23	162,732			

*** Significant at the 0·1% point.

Treatments	*Yield of grass in pounds per acre*	*Percentage of mean yield*
Mahapangiri	19,809 ..	100·5
Lenabatu	19,621 ..	99·5
Significant difference	2,628 ..	13·3
No manure	15,286 ..	78
Nitrogen alone	15,736 ..	80
Nitrogen, phosphate and potash	28,122 ..	143
Significant difference	3,216 ..	16
Mean yield	19,715 ..	100

Table 6—Analysis of Variance and Summary of Yields of the Fourth Year ending June, 1943

	Degrees of Freedom	*Sum of Squares*	*Mean Square*	*Variance Ratio*	*F. values for Significance at (0·1% point)*
Varieties ..	1 ..	4,267 ..	4,267		
Fertilizers ..	2 ..	298,215 ..	149,107	.. 54·64 ***	.. 11·34
Variety × Fertilizer	2 ..	5,553 ..	2,776		
Blocks ..	3 ..	22,208 ..	7,403		
Error ..	15 ..	40,943 ..	2,729		
Total ..	23	371,186			

*** Significant at the 0·1% point.

Treatments	*Yield of grass in pounds per acre*	*Percentage of Mean yield*
Mahapangiri	23,516 ..	105
Lenabatu	21,282 ..	95
Significant difference	3,804 ..	17
No manure	14,145 ..	63
Nitrogen alone	17,600 ..	79
Nitrogen, phosphate and potash	35,451 ..	158
Significant difference	4,656 ..	20
Mean yield	22,399 ..	100

Table 7—Analysis of Variance and Summary of Yields of the Fifth Year ending June, 1944

	Degrees of Freedom	*Sum of Squares*	*Mean Square*	*Variance Ratio*	*F. value for Significance at (0·1% point)*
Varieties	1	216	216		
Fertilizers	2	140,850	70,425	36·26 ***	11·34
Variety × Fertilizer	2	659	329		
Blocks	3	6,343	2,114		
Error	15	29,127	1,942		
Total	23	177,195			

*** Significant at the 0·1% point.

Treatments	*Yield of grass in pounds per acre*	*Percentage of mean yield*
Mahapangiri	16,710	97
Lenabatu	17,687	103
Significant difference	3,192	19
No manure	9,528	55
Compost and Citronella ash	16,836	98
Groundnut cake, saphos, and muriate of potash	25,233	147
Significant difference	3,928	23
Mean yield	17,199	100

Table 8—Analysis of Variance and Summary of Yields of the Sixth Year ending June, 1945

	Degrees of Freedom	*Sum of Squares*	*Mean Square*	*Variance Ratio*	*F. value for Significance at (0·1 % point)*
Varieties	1	1,118	1,118		
Fertilizers	2	85,005	42,502	38·36 ***	11·34
Variety × Fertilizer	2	356	178		
Blocks	3	6,066	2,022		
Error	15	16,621	1,108		
Total	23	109,166			

*** Significant at the 0·1% point.

Treatments	*Yield of grass in pounds per acre*	*Percentage of mean yield*
Mahapangiri	11,482	95
Lenabatu	12,676	105
Significant difference	2,424	20
No manure	6,334	52
Compost and Citronella ash	11,412	94
Groundnut cake, saphos, and muriate of potash	18,490	153
Significant difference	2,960	24
Mean yield	12,079	100

In none of the years did the two varieties differ significantly although *Lenabatu* generally out-yielded *Mahapangiri*.

Curves showing the fertilizer effects on the two varieties are presented in Fig. 1. Table 9 gives yield figures relating to these curves. Considering the unmanured treatments shown in the curves, it is seen that yields are highest in the second year, and thereafter there is a rapid and steady decline, which reaches uneconomical levels at the end of the sixth year. With the complete NPK mixture of artificial fertilizer, spectacular increases in yield were obtained, which reach a maximum in the fourth year. Even in the sixth year the yield of the NPK treatment is as much as the highest yield obtained without manuring, viz., the yield of the unmanured plots in the second year. Curves relating to yield of oil are presented in Fig. 2.

The Extraction and Yield of Oil

The extraction of oil was effected by steam distillation in experimental stills. The oil was wilted in the shade for about a day and then used for distillation.

In the first five harvests, distillation was done in the Chemical Laboratory at Peradeniya. Differences between plots were only in respect of varieties, and therefore a single sample of fresh grass of each of the varieties was drawn from the produce of all plots and blocks. A known weight of each sample (about 100 lb.) was despatched to Peradeniya immediately after wilting. On receipt this grass was weighed and an aliquot taken for distillation. The oil obtained from this sample was dried, measured and weighed. The weights of oil per plot at each cutting were thus obtained.

After the commencement of manuring in 1941, a direct-heating essential oil still of 40-gallon capacity was installed at Mapalana, and this was used for distillation of all samples. Adequate precautions were taken to clean out the still before use and again at the end of each distillation.

The yield of oil, expressed in pounds per acre for each of the treatments, is given in Table 10. A comparison of the total yield of oil obtained over six years in each of the treatments indicates that *Mahapangiri* yielded more oil than *Lenabatu*. Moreover, striking increases in the yield of oil were obtained with application of fertilizers. The plots manured with the complete NPK mixture of artificial fertilizer gave over the four-year manurial period nearly four times the yield of oil of the unmanured plots.

In Table 11, the oil content of the two varieties, expressed as a percentage of the weight of oil on fresh weight of grass, indicates that in general *Mahapangiri* has a higher oil content than *Lenabatu*. This difference appears to even out in subsequent years. It will be observed that figures of percentage oil show a considerable amount of variation from harvest to harvest. This may be related to weather conditions and also to difficulties in recovering the full quantity of oil in each distillation, in spite of precautions taken. The average value of all harvests should however be more reliable. The mean values accordingly appear to indicate that manuring with the complete NPK mixture does at any rate help the grass to maintain its oil content over the years.

In Table 12 the " total gereniol " contents of samples of oil of the two varieties are shown. These figures confirm the superiority of *Mahapangiri* over *Lenabatu* in respect of quality of oil.

On these comparisons of yield and quality of oil of the two varieties, *Mahapangiri* should be the more profitable variety to grow. Manuring with a complete NPK mixture was indeed

the most important method of increasing yields. Moreover, with regular manuring, replanting of citronella grass is not essential, except perhaps at long intervals.

Table 9—Yield of citronella grass in pounds per acre, indicating response of Mahapangiri and Lenabatu to fertilizers

		First Year ending June, 1940	*Second Year ending June, 1941*	*Third Year ending June, 1942*	*Fourth Year ending June, 1943*	*Fifth Year ending June, 1944*	*Sixth Year ending June, 1945*
Mahapangiri A	1.	6743	20983	15581	14513	8900	5361
	2.	6868	20606	16419	17675	16314	10932
	3.	7308	19748	27434	38366	25131	18094
Lenabatu B	1.	6177	21298	14995	13780	10157	7309
	2.	8083	20698	15058	17529	17361	11895
	3.	8858	23392	28817	32544	25550	18806

Table 10—Yield of citronella oil expressed in pounds per acre, indicating response of Mahapangiri and Lenabatu to fertilizers

Fertilizer Treatments		*No Fertilizers*		*Fertilizers Applied*					
		First Year ending June, 1940	*Second Year ending June, 1941*	*Third Year ending June, 1942*	*Fourth Year ending June, 1943*	*Fifth Year ending June, 1944*	*Sixth Year ending June, 1945*	*Total 3rd-6th Years*	*Total of Six Years*
Mahapangiri A	1.	34·34	112·05	38·95	39·16	31·62	15·92	125·65	272·04
	2.	34·97	97·38	69·74	56·96	72·67	49·21	248·58	380·93
	3.	37·49	95·70	99·06	162·09	138·64	103·66	503·45	636·64
Lenabatu B	1.	30·99	70·75	48·38	34·97	39·16	21·57	144·08	245·82
	2.	40·12	69·53	57·59	56·96	67·02	44·82	226·39	336·04
	3.	44·19	78·11	123·14	125·03	115·60	94·24	458·01	580·31

Summary

1. Manuring with a complete artificial fertilizer mixture (NPK) was the most effective method of increasing yields of citronella grass and oil. Grass yields were two to three times those from unmanured plots. The total yield of oil over the four-year manurial period was nearly four times that of the unfertilized treatment.

2. Nitrogen alone did not increase yields. Phosphate and potash were found particularly important in the manuring of citronella.

3. With regular applications of a complete fertilizer mixture, replanting is not essential, except perhaps at long intervals. Even in the sixth year the yield of grass from the plots receiving this treatment was nearly as much as the highest yield obtained without manuring.

4. *Lenabatupangiri* generally outyielded *Mahapangiri* in weight of grass, but the difference did not exceed ten per cent. in any one year. In no instance was this difference statistically significant.

5. Grass of *Mahapangiri* in the early stages showed a higher oil content than that of *Lenabatu*, but with advancing age these differences were evened out.

6. Manuring has a beneficial effect on oil content, optimum results being obtained with the complete fertilizer. This enabled the grass to maintain its original oil content.

7. *Mahapangiri* oil has a higher " total gereniol " content than oil of *Lenabatu*.

8. On comparisons of the yield and quality of oil, *Mahapangiri* is the more profitable variety to grow, if fertilizers are used.

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Table 11—Oil content of varieties expressed as a percentage of the weight of oil on the fresh weight of grass

Harvests before manuring	*Lenabatu*	*Mahapangiri*
1st	·50	·51
2nd	·25	·45
3rd	·55	·72
4th	·34	·43
5th	·34	·34
Average	·40	·50

Harvests after manuring	*Lenabatu Fertilizer treatments*			*Mahapangiri Fertilizer treatments*		
	1	2	3	1	2	3
1st	·25	·27	·23	·21	·29	·24
2nd	·26	·43	·53	·35	·47	·54
3rd	·60	·55	·68	·26	·43	·33
4th	·27	·38	·57	·22	·37	·43
5th	·20	·29	·28	·22	·25	·26
6th	·26	·28	·33	·23	·33	·49
7th	·31	·49	·53	·37	·36	·65
8th	·30	·37	·42	·34	·39	·45
9th	·44	·34	·51	·41	·46	·55
10th	·39	·39	·41	·34	·41	·46
11th	·46	·46	·47	·45	·53	·60
12th	·31	·35	·37	·23	·41	·59
13th	·33	·25	·46	·21	·34	·43
14th	·29	·41	·50	·45	·50	·81
15th	·28	·42	·45	·38	·53	·61
16th	·24	·53	·61	·25	·53	·58
Average	·32	·39	·46	·31	·41	·50

Table 12—Gereniol content expressed as a percentage by weight of Citronella oil

Harvests	*Mahapangiri*	*Lenabatu*
1st	70·2	56·7
2nd	73·0	59·9
3rd	69·4	48·2
4th	61·0	56·6
5th	63·1	56·4
6th	70·7	50·6
7th	71·7	52·7
8th	71·3	56·4
9th	71·4	53·6
10th	71·9	52·2
11th	72·2	52·1
12th	72·2	53·0
13th	75·6	54·8
14th	69·7	55·8
15th	69·7	55·9
Mean	70·2	54·3