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Surface sowing a simple and safe technique for pasture establishment in the wet upper montane zone of Ceylon

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(Received August, 1970.)

INTRODUCTION

THE wet upper-montane zone of Ceylon, generally upwards from 4,000′, has a wet tropical to temperate climate and is said to comprise about 50,000 acres. It may be divided into two distinct land classes according to natural vegetation (2) (4) viz :—

(*a*) Montane rain-forest (Jungle) 34,000 ac.

(*b*) Grassland (Patana) 15,000 ac.

The jungle vegetation has been described as follows :—

The characteristic trees of this zone are species of damba (*Syzygium*), kina (*Calophyllum walkeri*), val sapu (*Michelia nilagirica*), and species of *Litsea. The* undergrowth consists of nelu (*Strobilanthes spp*) which flower, fruit and die about every twelve years. Masses of mountain bamboo (*Indocalamus Chimonobambusa*) also occur, and the jungle abounds in epiphytic orchids and mosses (7).

Some authors regard the patana as a subclimax vegetation that has developed from clearing jungle and constant burning over a long period of time, others think of it as a natural phenomenon (5) (6). Three main grassland communities have been recognised in the region and are described (7) thus.

(i) The "mana" community (*Cymbopogon confertiflorus*) dominant.

(ii) The "gavara" community (*Chrysopogon zeylanicus*) dominant.

(iii) The "pini-baru-tana" community (*Themeda tremula*) dominant.

But there are numerous intermediate types of grassland associations that represent various stages of succession.

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In its natural state, the vegetation of this montane zone retards surface run-off and therefore serves to build up groundwater reserves. Some of the major rivers of the Island have their origin here. Certain areas are being utilised in the following ways, viz :—

(i) Tea cultivation.

(ii) Timber production.

(iii) Vegetable cultivation.

(iv) Livestock and potato farming.

On the steeper slopes cultivation is generally undesirable since it accelerates soil erosion and leaching of plant nutrients. The Land Utilization Committee (4) has recommended as follows :—

" 1. The Horton Plains area (2400 ac.) should not be alienated for any cultivation.

2. There should not be any cultivation permitted on forest land above 6000′ elevation.

3. The wet patana grassland, exclusive of those of the Horton Plains, could be used for potato cultivation and pasture.

4. The production of the Islands' requirements of seed potato material requires an extent of 2000 ac. of land preferably above 6000′. Since potato is to be grown in a " one in four season " rotation with an improved pasture ley, a total demand of 8000 ac. would have to be met ".

Patana soils are rich in humus, varying in thickness from a few inches to a few feet. The Land Utilization Committee is of opinion that it is in these wet patanas, with their heavy, fairly evenly distributed rainfall that most might be expected for pasture development (4) (7). However various attempts, to establish pasture on these soils in the conventional manner, have resulted in costly failures.

Leguminous species sometimes do not even become established or may disappear within a few weeks of sowing. On jungle soil, pasture establishment, after cultivation, may be more reliable than on patana land but is not always as successful as it should be. In both circumstances the costs of seed bed preparation can be very high.

Since it has been shown in other countries that improved pastures can be developed without cultivation, it was decided to investigate the possibilities of doing this in both jungle and patana areas.

MATERIALS AND METHODS

At Ambawela, where the experiments reported in this paper were carried out, the elevation is 6000′ and the climate is temperate. Rainfall, mainly from both north-east and south-west monsoons, during the past ten years has averaged 98 in. on 205 wet days per annum. In addition there are many misty days on which no rainfall is recorded. Air temperatures range from about 28°F to 82°F (7), the light frosts occurring during January, February and March. Soils are generally very acidic. Typical analyses (3) are as follows :—

	p. H	*Organic Matter* (%)	*Nitrogen* (%)	*Ex.bas es* (*m.e/100g*)	*Ex. K* (*me/100g*)	*Av. P** (*lb/ac*)
Virgin jungle	4.68	13.9	0.60	7.91	0.46	16.0
Virgin patana	4.83	15.4	0.46	1.28	0.16	10.0

*Truog

Field experiments (unpublished data) indicate that jungle soils are deficient in nitrogen, phosphorus, sulphur, boron and molybdenum, and patana soils in potassium and magnesium, as well.

The experiment consisted of sowing twelve legumes and one grass in uncultivated strips and observing their establishment and performance in jungle and patana lands.

(*a*) *Jungle*—An area of 0.2 ac. was selected for the surface sowing experiment. It had been " underbrushed " and burnt during early 1968 leaving only the high shade trees and stumps and had subsequently been planted with *Pennisetum clandestinum* (kikuyu grass) in June of that year. Underbrushing involves, the lopping of the understory, piling it in heaps and burning during dry weather. Some of the weaker tall trees subsequently had fallen over, and in places where there were clumps of trees a little thinning out was done. Some places had a fair amount of weeds and these were removed by hand weeding, but otherwise the land was undisturbed. Legume seeds, to be sown, were inoculated with peat inoculum and pelletted with lime or saphosphosphate according to the procedure normally followed. (1)

Twelve strips, each 11′ × 66′, were marked out and subdivided, into sub-strips 16′ × 6″ long for differential treatment with potassic fertilizer. Each strip received ordinary superphosphate at 560 lb. and ground dolomitic limestone at one ton per ac. Two sub-strips on each strip were given, at random, sulphate of potash at 112 lb. per acre, the other two were not treated with potassic fertilizer.

Pelletted legume seeds plus *Festuca arundinacea* seed and fertilizer were mixed just prior to sowing, on October 10th, 1968, and then broadcast, by hand, as shown in table No. 1.

Table No. 1—Species and cultivars sown in both jungle and patana plots

Group	*Strip Number*	*Species*	*Cultivar*	*Seed rate lb. per ac.*
A ..	1 ..	*Trifolium subterraneum* ..	Dwalganup ..	20
A ..	2 ..	do. do. ..	Mt. Barker ..	20
A ..	3 ..	do. do. ..	Tallarook ..	20
A ..	4 ..	*Trifolium pratense* ..	Pennscott ..	20
A ..	5 ..	*Trifolium repens* ..	Ladino ..	10
A ..	6 ..	do. do. ..	Huia ..	10
A ..	7 ..	*Lotus corniculatus* ..	San Gabriel ..	10
B ..	8 ..	*Phaseolus atropurpureus* ..	Siratro ..	20
B ..	9 ..	*Desmodium uncinatum* ..	Commercial ..	20
B ..	10 ..	*Glycine javanica* ..	Clarence ..	20
B ..	11 ..	do ..	Cooper ..	20
B ..	12 ..	do ..	Tinaroo ..	20

Seeds in group " A " were pelletted with calcium carbonate and those in Group " B " with saphosphosphate.

(*b*) *Patana*—An undisturbed area of patana land, which had been grazed intermittently by farm cattle, was fenced off, pegged out, and sown as for the jungle plot. The ground was completely covered with a low-grass sward the most common species being *Arundinella villosa, Chrysopogon montanus, Eulalia phaeothrix, Ischaemum indicum* and *Tripogon bromoides*. A few weeds were present, the most prominent being *Anaphalis subdecurrens, Justicia procumbens* and *Osbeckia cupularis*.

Amounts of rainfall from October, 1968, until September, 1969, are shown in appendix No. 1, and weather conditions from time of sowing until taking establishment counts, in appendix No. 2.

RESULTS

As germination was complete within three weeks of sowing, seedling populations were determined by making quadret counts at the end of October. Results are shown in Table No. 2.

Table No. 2—Establishment counts obtained on October 31 (jungle) and on November 1, 1968 (patana)

Strip	Species	Cultivar	Germinable* seeds sown (sq/lk)	ESTABLISHMENT: Seedlings sq/lk: jungle	Seedlings sq/lk: patana	Percentage of seeds sown: jungle	Percentage of seeds sown: patana
1.	*T. subtemaneum*	Dwalganup	12·1	12·1	6·2	100·0	51·2
2.	do.	Mt. Barker	8·1	ND	4·2	ND	51·8
3.	do.	Tallarook	12·3	ND	5·3	ND	43·0
4.	*T. pratense*	Pennscott	41·0	20·1	12·6	49·0	30·7
5.	*T. repens*	Ladino	72·0	27·3	13·4	37·9	18·6
6.	do.	Huia	50·0	ND	10·8	ND	21·7
7.	*L. corniculatus*	San Gabriel	18·	4·7	4·0	25·0	21·7
8.	*P. atropurpureus*	Siratro	3.0	1·6	0·7	53·0	23·8
9.	*D. uncinatum*	Commercial	16·9	5·0	4·2	29·5	24·8
10.	*Glycine javanica*	Clarence	3·8	0·1	0·4	2·1	10·5
11.	do.	Cooper	4·2	0·7	0·6	16·6	14·2
12.	do.	Tinaroo	6·7	2·7	0·8	40·2	11·9
	Festuca arundinacea	Tall	45·4	10·2	ND	22	ND

* Based on germination and purity test of original sample. Seeding establishment in the jungle was considerably better than on the patana plot. N.D. = not determined.

Healthy nodules developed near the crown of *Trifolium* plants, at an early stage of growth, but took longer to develop on species in other genera. The apparent vigour of the various species was judged, on February 2nd, 1969, by giving a value of ten to the best one and a value to each of the others, in descending order.

The result is shown in table No. 3.

Table No. 3—Evaluation of various species, on a 0-10 scale on February 2, 1969

Strip	Species	Cultivar	Jungle plot (+K)	Jungle plot (−K)	Patana plot (+K)	Patana plot (−K)
1.	*T. subterraneum*	Dwalganup	10	8	5	1
2.	do.	Mt. Barker	10	10	7	2
3.	do.	Tallarook	8	4	7	2
4.	*T. pratense*	Pennscott	7	7	9	5
5.	*T. repens*	Ladino	7	7	10	4
6.	do.	Huia	5	5	6	2
7.	*Lotus corniculatus*	San Gabriel	*	*	*	*
8.	*P. atropurpureus*	Siratro	1	1	*	*
9.	*D. uncinatum*	Commercial	8	5	*	*
10.	*Glycine javanica*	Clarence	1	1	*	*
11.	do.	Cooper	1	1	*	*
12.	do.	Tinaroo	3	1	*	*

*Population insufficient for evaluation.

In the jungle area, from February onwards, all the *Trifoliums* developed well and although *Desmodium* was a little slow in starting, after the cold months were over made tremendous growth. The *Glycines* were slow at first but steadily improved subsequently. *Phaseolus* produced a little herbage but *Lotus* never got beyond the seedling stage. Tall fescue and kikuyu developed very well and with the strong legume growth produced a good mixed pasture.

On the patana plot the development of the legumes was similar but generally less vigorous than in the jungle and during February *Desmodium Phaseolus* and *Glycine* were completely cut back by the frost because of the absence of protective tree cover. During the first twelve months a proper assessment of the development of the fescue in the patana sward was not possible because the plants were too tiny.

About one month after sowing the jungle plot, a small response to potassium was evident on strips sown with *D. uncinatum*, Tallarook subterranean clover and Tinaroo glycine but subsequently this effect disappeared.

On July 10th, 1969, as a strong response to potassium was still evident, on the patana plot, the unsown headland and the best of the sown plots were sampled for yield and composition. Results obtained are shown in table No. 4.

Table No. 4—Yield, legume and crude protein content of selected plots within patana experimental area

Treatment	*Sulphate of Potash*	*Yield* (*dm/ac*) (*lb.*)	*Yield* (*dm/ac/day*) (*lb*)	*Botanical Composition* (%) (*Legume*)	*Crude Protein* (%) (*dm*)
Unsown patna (control)	—	1,430	5·3	0	8·5
Mt. Barker sub.	+	3,321	12·3	70	12·0
do	–	2,238	8·2	50	10·5
Pennscott red	+	3,976	14·7	30	12·3
do	—	2,188	8·1	15	9·9
Ladino white	+	3,748	13·8	25	13.7
do	—	1,966	7·2	10	10·2
Huia white	+	4,285	15·8	50	15·5
do	—	2,041	7·5	30	11·4

+ indicates treatment with sulphate of potash.

At various times, during the experiment, observations were made on the development and regeneration behaviour of the sown species. Information obtained is summarised in table 5.

TABLE 5.—Dates on which (a) seedlings emerged (b) root nodules first observed (c) first flower appeared (d) viable seed developed and annuals subsequently regenerated from seed. All seed originally sown in October, 1968

Treatment		*Establishment*				*Regeneration*
Species	*Cultivar*	(*a*) *Emergence*	(*b*) *Nodules*	(*c*) *Flowering*	(*d*) *Seeding*	*Emergence*
T.subterraneum	Dwalganup	Oct. 24th, 1968	Oct. 30th, 1968	Jan. 11th, 1969	Feb. 12th, 1969	May 11th, 1969
do.	Mt. Barker	do.	do.	Feb. 25th, 1969	Apr. 11th, 1969	Jun. 23rd, 1969
do.	Tallarook	do.	do.	Apr. 19th, 1969	May 20th, 1969	July 23rd, 1969
T.pratense	Pennscott	do.	do.	May 20th, 1969	—	Perennial
T.repens	Ladino	do.	do.	—	—	do.
do.	Huia	do.	do.	Apr. 11th, 1969	—	do.
L. corniculatus	San Gabriel	Oct. 31st, 1968	—	—	—	do.
P.atropurpureus	Siratro	do.	Nov. 22nd, 1968	—	—	do.
D.uncinatum	Commercial	Oct. 24th, 1968	do.	July 23rd, 1969	—	do.
G.javanica	Clarence	do.	do.	—	—	do.
do.	Cooper	do.	do.	—	—	do.
do.	Tinaroo	do.	do.	Apr. 11th, 1969	—	do.

The Dwalganup and Mt. Barker cultivars of subterranean clover flowered prefusely, Tallarook quite well, but flowering on all other cultivars was very spare, until the end of September 1969.

DISCUSSION

After underbrushing jungle there is normally some woody regeneration and a volunteer growth of various weeds. The former does not present any real problem, as it is easily destroyed, but the longer the interval between burning and sowing the more serious the competition from weed growth becomes. If a substantial amount of weed growth has developed before sowing, it is necessary to reduce this by controlled grazing at regular intervals.

Since the pasture seed is dropped on the surface of the ground and has very little protection from drying out, sowing is best undertaken during the rainy season. In this experiment it was done in October which is the beginning of the north-east monsoon period. However because of shady conditions and less competition, conditions for germination in the jungle are generally better than on the patana, so that, time of sowing in the former is less critical than in the latter environment. As will be seen from the weather records, rainy days during the north-east monsoon period were normal during October but below average during November and December. As temperatures were steadily falling after sowing, the cold sensitive genera such as *Phaseolus, Glycine and Desmodium* made slower growth than the *Trifoliums*. Although growth was not seriously retarded in the jungle, because of the protection against frost by the tree canopy, on the open patana, legumes other than the *Trifoliums*, were completely burnt off during February of 1969. It is more than likely that nodulation and thus competition of the species intolerent of lower temperatures was poorer than if they had been sown during the south-west monsoon period when air temperatures are higher.

On the other hand, soil temperatures under undisturbed patana and in the shady environment of the underbrushed jungle are more favourable for the development of pasture seedlings than on bare cultivated soil. This could well explain successful establishment from surface sowing but failure when seed is sown on a well prepared seed bed in the conventional manner.

For each of the three cultivars of *T. subterraneum*, day length was sufficient to induce flowering, which occurred in the expected sequence viz. first Dwalganup then Mt. Barker and last Tallarook.

A strong regeneration from seed occurred with Dwalganup during May, and in June and July in the Mt. Barker and Tallarook cultivars respectively. This is during the period of the south-west monsoon. Thus all three cultivars of subterranean clover went through their life cycles in a normal manner, and, provided they are given proper management should remain as permanent elements in the pasture. Mt. Barker appears to be more suited to the wet upper-montane environment than either of the other two cultivars of subterraneum clover.

Although both cultivars of white clover suffered severely during the dry conditions in January and February they recovered well and the evidence from other parts of the Ambawela farm is that this species will persist. Since it propagates by rooting from stolons, seed production by this species is relatively unimportant. At this stage it appears that the Huia cultivar may be the better of the two. On the other hand the inability of red clover to produce any substantial amount of seed coupled with the fact that it does not propagate vegetatively, would indicate that it is unlikely to persist for very long. *L corniculatus* failed in both jungle and patana sowings, possibily because of ineffective nodulation.

The most promising sub-tropical legume sown is silver-leaf desmodium. This has grown very vigorously in the jungle and commenced flowering in July of 1969. For first twelve months after sowing its performance on the patana has been less impressive because it suffered badly from frost injury, but had it been sown during the south-west instead of in the north-east monsoon period, it may have developed much better. *Glycine* and *Phaseolus* have been unimpressive so far although the former is steadily improving in the jungle.

Reference to appendix No. 1 will show that for twelve months, after sowing in October, the conditions were generally much drier than usual, particularly during November. Therefore it may be safely assumed that if satisfactory results were obtained from surface sowing under such conditions, this method can be recommended with confidence.

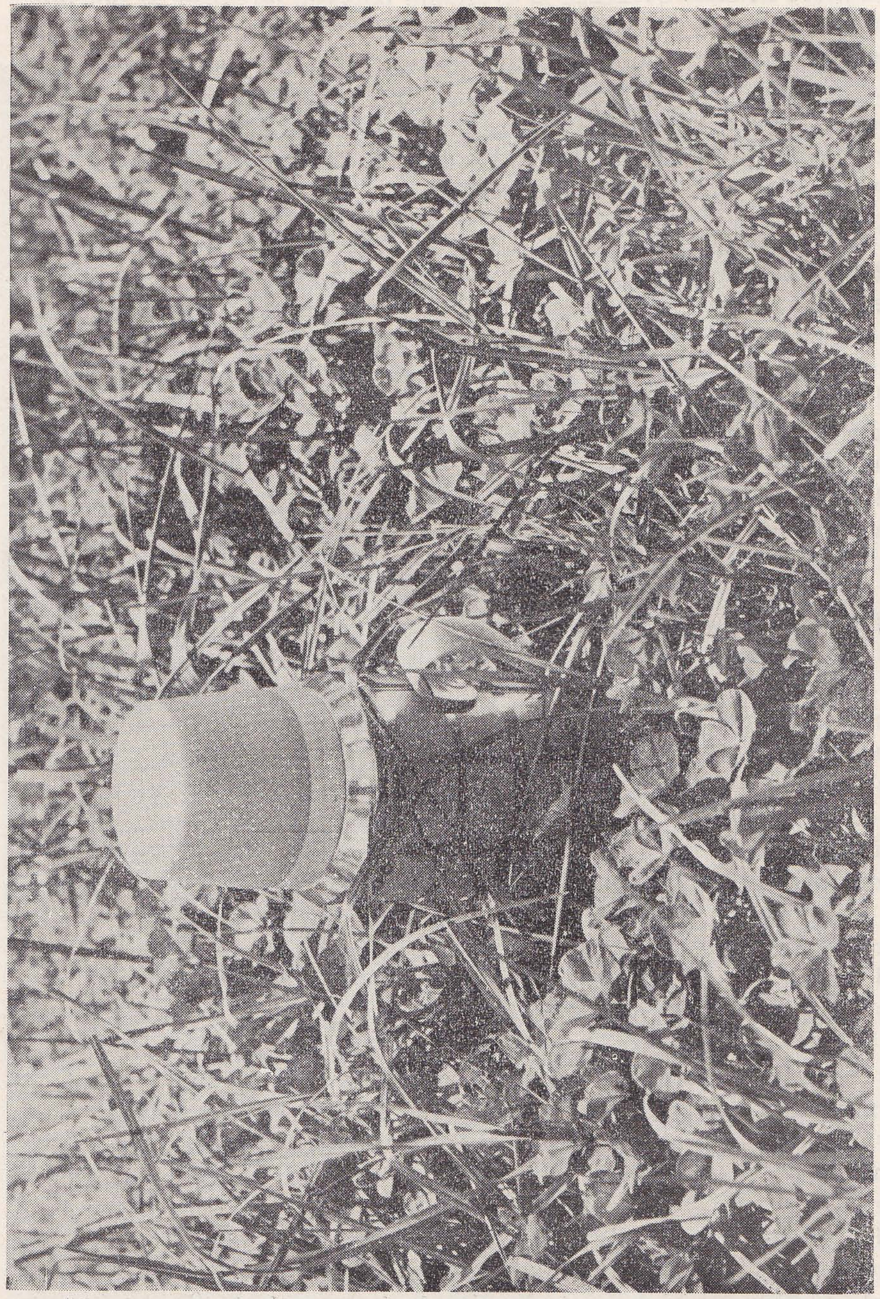
Soil analyses and various experiments (unpublished data) indicate that jungle soils are less deficient in potassium than those of the patana. In the present experiments the marked response to potassium on the patana (see tables Nos. 3 and 4) and the lesser transient reponse by only some of the sown legumes in the jungle plot generally conforms to what was expected. This may indicate that some of the legumes have a higher requirement for potassium than others or that observations in the jungle were upset by better growth

I. TRIFOLIUM SUBTERRANEUM established on patana soil at Ambawela by sufraoe sowing. L. H. S. with potassium, R. H. S. without potassium. Note marked response to potassium. (Photo by J. Keith) on ash-beds remaining after underbrushing and burning. Therefore until more definite evidence is available potassic fertilizer at not less than one cwt. per ac. is recommenced, only for patana sowing. Both superphosphate and dolimitic lime are needed in both situations since soils are deficient in phosphorus, sulphur and calcium. Ordinary superphosphate, which contains sulphur, should be used, and slaked dolomite in preference to ground dolomitic limestone, as the former provides both calcium and magnesium in a readily available form.

The satisfactory nodulation of most of the sown legumes indicates that the technique of inoculation and pelletting with finely powdered calcium carbonate in the case of the *Trifoliums* and with rock phosphate for the others was satisfactory. In the jungle the good establishment of tall fescue and the ability of this grass to persist and compete with the kikuyu indicates that the former species can be included in jungle sowings to provide additional herbage, during the cold January-February-March period, when the growth rate of the kikuyu is at a minimum. Fescue flowers and sets seed readily in this environment. As yet it is too early to say whether it can be satisfactorily established on patana from surface sowing.

Since establishment, from all sowings, was good and generally quite comparable with what might be expected from a successful sowing on a prepared seed bed and as with both methods the type and quantity of fertilizer needed would be similar, the essential difference between costs of establishment from surface and conventional sowing would be the difference between cost of underbrushing and of clearing and cultivation on jungle land, and between no cultivation and cultivation on patana. Estimates for these operations are Rs. 54 for underbrushing Rs. 250 for clearing jungle, and Rs. 300 for cultivating and preparing a seed bed. Thus the saving from surface sowing offsets the cost of the seed except for two species even at the rates used which are probably much higher than necessary to establish a satisfactory stand of sown species.

In its natural state, ten acres of patana may just provide a maintenance ration for one cow (see table No. 4) whereas jungle provides very little graze at all. This experiment shows that both the quantity and the quality of patana herbage can be considerably improved by surface sowing and that in the jungle a mixed pasture of high quality can be established by using this method instead of the conventional one of clearing and cultivation. For large areas aerial seeding would seem to be the logical method to use. The technique of surface sowing if followed correctly, provides a way of establishing pasture in the wet-montane zone with little or no risk



2. Mixed pasture of TRIFOLIUM SUBTERRANEUM, FESTUCA ARUNDINACEA, & PENNISETUM CLANDESTINUM developed on jungle land at Ambawela by surface sowing seed of the first two species and planting kikuyu grass.
(Photo by J. Keith)

from soil erosion and disturbance of the balance of nature but with the added advantages that the soils are being enriched by the fertilizer and animal excreta and much needed animal production is being obtained.

Since virgin jungle soil does not readily erode, there is little or no risk of losing soil during the period between burning and pasture establishment.

There is no evidence to show that the replacement of the understorey of the jungle vegetation by pasture significantly reduces the intake of the rain water or flow of subsoil water to the rivers.

Overseas experience is that the better the establishment of the pasture the less the run-off of rainfall. Hence there is everything to be gained and nothing to be lost by improving the pasture sward on the patana land.

SUMMARY

This experiment demonstrates the possibility of establishing improved pastures on undisturbed patana and in underbrushed jungle in the wet-montane zone provided the various operations are timed to coincide with suitable climatic conditions and the necessary plant nutrients are used. Various aspects of the surface sowing technique are discussed.

Trifolium subterraneum, T. repens, T. pratense and *Desmodium uncinatum* were the most promising of the species used. This technique could be used to make an important contribution to solving the problem of providing cheap and effective forage for animals in the wet-montane zone of Ceylon.

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Appendix No. 1

Ambawela rainfall, and offsets from average, for the twelve months following sowing on October 10, 1968

Month	*Year*	*Amount (in)*	*Offset (in.)*	*Rainy days (No.)*	*Offset (No.)*
October	1968	14·14	+ 2·80	21	+ 1
November	1968	5·33	— 6·40	10	—11
December	1968	12·41	+ 3·04	13	— 4
January	1969	7·07	— 0·17	8	— 6
February	1969	2·04	— 3·10	5	— 5
March	1969	1·09	— 4·40	4	— 6
April	1969	12·86	+ 3·77	16	— 1
May	1969	10·87	+ 2·55	16	— 2
June	1969	8·25	— 0·01	20	— 2
July	1969	6·31	— 1·21	17	— 4
August	1969	6·06	— 0·57	16	— 3
September	1969	12·66	+ 5·09	13	— 5

Appendix No. 2

Daily weather conditions at Ambawela from sowing seed on October 10th, 1968, until seedlings were counted at the end of the month

Occtober 11th —	Bright till noon, thereafter rain
Otober 12th —	Bright till noon, thereafter rain.
October 13th —	Bright till noon, thereafter rain.
October 14th —	Alternately sunny and bright till noon, then rain.
October 15th —	Bright till noon, then rain.
October 16th —	Bright till noon, then rain.
October 17th —	Bright till noon, then rain.
October 18th —	Very bright all day.
October 19th —	Very bright all day.
October 20th —	Bright till noon, thereafter rain.
October 21st —	Bright till noon, thereafter rain.
October 22nd —	Bright till noon, thereafter rain.
October 23rd —	Overcast day but no rain.
October 24th —	Bright for whole day.
October 25th —	Bright for whole day
October 26th —	Bright for whole day.
October 27th —	Bright till noon, thereafter rain.
October 28th —	Bright till noon, thereafter rain.
October 29th —	Bright till noon, thereafter rain.
October 30th —	Bright till noon, thereafter rain.
October 31st —	Bright till noon, thereafter rain.

N.B.—A bright morning with afternoon rain is characteristic of the weather during the early north-east monsoon period.

Tracer studies on the efficiency of combined nitrogen and phosphorus fertilizers for rice as influenced by time and method of application

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(Received August, 1970).

INTRODUCTION

Combined sources of nitrogen and phosphorous such as ammonium phosphates and nitric phosphates contain relatively high proportions of plant nutrients. They are of advantage because costs due to shipping, handling and storage are less in comparison to fertilizers containing only one major plant nutrient.

Interest in nitric phosphate fertilizers, the products of the acidulation of rock phosphate with nitric acid, has been stimulated due to shortage of sulphur and increased production of nitric acid in the world. Nitric acid has two roles in the manufacture of nitric phosphate, (*a*) solubilizing of rock phosphate, and (*b*) supplying of nitrogen.

The large scale production of nitric phosphates or nitro-phosphate in France, Italy, Holland and U.S.A. (TVA) has been reported (4). Results of greenhouse and field investigations with fertilizers made by acidulating rock phosphate, with nitric acid or with a mixture of nitric and phosphoric acids, indicate that both nitrogen and phosphorus are available for plant growth and that this fertilizer is almost as efficient as superphosphate and ammonium nitrate on acid soils. (9, 11, 12).

Ammonium phosphates are the products of neutralizing phosphoric acid with ammonia and has in recent years become increasingly important in bulk blending for the manufacture of high analysis granular fertilizers.

Ammonium phosphate was not found to be significantly different from steamed bone meal, superphosphate or mineral phosphate by Haig and Joachim (3) in studies on the form of phosphatic fertilizer for rice at Peradeniya. Chandraratna and Fernando (2) observed no significant diffierence between superphosphate and ammophos (16. : 20, N : P_2O_5) for rice at Tissamaharama during the first season, but during the next three seasons they found ammophos was superior to superphosphate. Fertilizer trials conducted in cultivators' fields in various locations of the island by Ponnamperuma (8) showed ammonium phosphate to be equally good as ammonium sulphate and urea as a source of nitrogen on the grey non-lateritic soils of the dry zone, but to be superior to other sources of nitrogen on the brown acid and strongly acid lateritic soils of the wet zone. At Paranthan (1) ammonium phosphate was found to be superior to concentrated superphosphate, rock phosphate and bone meal for rice.

This paper contains results of the fifth investigation using labelled fertilizers conducted in Ceylon under the Co-ordinated Contract Programme sponsored by the Joint FAO/IAEA Division of Atomic Energy in Agriculture. The results of earlier investigations in this series are already reported (5, 6, 7, 10). The objectives of the experiment were :

(i) to compare the efficiency of two different combined sources of nitrogen and phosphorus, ammonium phosphate and nitric phosphate with straight fertilizers ammonium sulphate and superphosphate ;

(ii) to compare the efficiency of these combined sources as influenced by shallow placement at transplanting and surface placement two weeks before primordial initiation.

EXPERIMENTAL

Fertilizers containing both nitrogen and phosphorus (ammophos-B and nitric phosphate) were compared with ammonium sulphate and superphosphate on rice at the Agricultural Research Station, Maha Illuppallama during the Yala season (May-October), 1967.

Important characteristics of the soil at the location of the experiment are present in Table 1 and mean monthly climatological data during the season are shown in Table 2. The experiment was a randomized complete block design of 10 treatments replicated 4 times. The sub-plots and their dimensions were as follows :—

1. Radioactive sub-plot .. 1.56 sq. meters
2. Intermediate yield sub-plot .. 1.88 sq. meters
3. Final yield sub-plot .. 3.44 sq. meters

The treatments were as follows :—

Treatment	Placement and Time: N-Fertilizer	Placement and Time: P-Fertilizer
1 ..	Ammonium sulphate applied at transplanting in rows at 5 cm. depth	Superphosphate applied at transplanting—broadcast on surface
2 ..	Ammophos-B applied at transplanting in rows at 5 cm. depth	Phosphate applied combined with nitrogen
3 ..	Nitric phosphate (25% soluble P) applied at transplanting in rows at 5 cm. depth	Phosphate applied combined with nitrogen
4 ..	Ammonium sulphate applied 2 weeks before primordial initiation—broadcast on surface	Superphosphate applied 2 weeks before primordial initiation—broadcast on surface
5 ..	Ammophos-B applied 2 weeks before primordial initiation—broadcast on surface	Phosphate applied combined with nitrogen
6 ..	Nitric phosphate (25% soluble P) applied 2 weeks before primordial initiation—broadcast on surface	Phosphate applied combined with nitrogen

7 .. Nitrogen, as ammonium sulphate, applied at transplanting in rows at 5 cmt depth at rate of 120 Kg N/hectare. Superphosphate at rate of 60 Kg. P_2O_5 /hectare applied at transplanting—broadcast on surface

8 .. Recommended local practice (Recommendation of the Department of Agriculture for the area)

33 Kg. P_2O_5 /hectare as concentrated superphosphate plus 31 Kg. K_2O/ hectare as muriate of potash (50% grade)—applied before transplanting—broadcast on surface

Nitrogen at rate of 53 Kg N/hectare as ammonium sulphate was split applied as follows :—

(i) $\frac{1}{4}$ — 2 weeks after transplanting—broadcast on surface ;
(ii) $\frac{1}{2}$ — 3 weeks before heading—broadcast on surface ;
(iii) $\frac{1}{4}$ — at heading—broadcast on surface

9 .. Received the basic 60 Kg P_2O_5 /hectare plus 60 Kg K^2O/hectare, with no nitrogen, applied broadcast on surface at transplanting

10 .. Received no fertilizer (Control)

Note.—All treatments including 7 and 9 (but not 8 and 10) received 60 Kg. K_2O hectare just before transplanting—broadcast on surface.

All treatments except 7, 8, 9 and 10 received 60 Kg N/hectare.

All treatments except 8 and 10 received 60 Kg P_2O_5 /hectare.

Treatments 7 and 8, and 9 and 10 were equal sized sub-plots of the yield response of and yield check plots respectively.

Radioactive and non-radioactive superphosphate and labelled and non-labelled nitrogenous fertilizers for all treatments except treatment 8 were received weighed and packeted from Joint FAO/IAEA Division of Atomic Energy in Food and Agriculture, Vienna, Austria. Chemical and isotopic analyses for nitrogen and phosphorus were done at the IAEA laboratories, Vienna, Austria.

The 4-4½ months *indica* variety of rice, H-4, was used in this experiment. The first plant sampling for determining N^{15} and P^{32} was done two weeks before primordial initiation (20 days after transplanting) from treatments 1, 2 and 3. The youngest fully expanded leaf from the largest tiller of every plant from those of the nine centre hills of the radioactive sub-plots was selected for sampling (Figure 1). The second leaf sampling was done at the stage of primordial initiation (42 days after transplanting). The leaf below the flag leaf, from the largest tiller of every plant from the 9 centre hills of the radioactive sub-plots of treatment 1 to 6 were sampled for N^{15} and P^{32} determinations. The third leaf sampling was done at heading (61 days after transplanting) exactly as described for the second sampling, from radioactive sub-plots 1 to 6 for N^{15} determinations. A harvest of 12 centre hills of the intermediate dry matter harvest yield sub-plots 1 to 6 was carried out to assess dry matter yields at the stage of primodial initiation (Figure 1).

RESULTS AND DISCUSSION

Percentage of Nitrogen and Phosphorous Derived from Fertilizers

The use of isotopically labelled fertilizers enables the quantitative determination of mineral nutrients derived by plants from applied fertilizers.

Nitrogen.—The percentage of fertilizer derived nitrogen in leaf tissue, grain and straw of rice plants is shown in Table 3. In the leaf tissue it was observed, as expected, that the percentage nitrogen derived from fertilizer decreased steadily with age of plants. Results of the 42 and 72 day leaf analysis show that application of any of the three nitrogen fertilizers at transplanting, in rows at 5 cm. depth, or 2 weeks before primordial initiation, as a broadcast application made no significant differences in the percentage of nitrogen derived from any of the three fertilizers. However, it shows that earlier application caused greater uptake of nitrogen from a fertilizer than later application, although differences did not reach statistical significance. Among the fertilizers it could be concluded that ammonium sulphate and ammophos-B are better sources of nitrogen than nitric phosphate as judged by plant uptake. The same general trends are observed in the data on fertilizer derived nitrogen in the grain, and in straw at final harvest. In the case of ammophos-B however, earlier application caused significantly greater uptake of nitrogen into grain than later application. Because the nitrogen content in the grain is related to that of protein a fertilizer or fertilizer treatment that increases grain nitrogen may be of value in increasing the nutritive quality of rice. Denitrification and leaching losses may have contributed to the relative inefficiency of nitric phosphate.

Phosphorous.—The effect of treatments on the utilization of phosphorous by plants is seen from the data on Table 4. It will be observed that nitric phosphate (placed at 5 cm. depth in rows) gave a significantly lower concentration of the element in the leaf tissue than superphosphate (broadcast) or ammophos-B (placed at 5 cm depth in rows) in plants at 20 days from transplanting. At the later sampling (42 days from transplanting) the differences in concentration of phosphorous in leaf tissue were not significant in treatments 1, 2 and 3, although the superphosphate treated plants contained considerably much more. Later application of fertilizers have caused greater concentration of phosphorous in leaf tissue than earlier application.

As expected the percentage of phosphorous derived from fertilizer from all sources is greater when applied at transplanting than at 2 weeks before primordial initiation. Nitric phosphate appears to be a relatively less efficient source of phosphorous (and of nitrogen, Table 3) when applied later in comparison to the other two sources.

Effect of Treatments on Plant Growth

Plant Height and Number of Tillers Per Hill.—The effect of fertilizer treatments on plant height and number of tillers per hill at three stages of growth are presented in Table 5.

It will be observed that there were highly significant differences in plant height due to treatments as early as 14 days from transplantng. Plants in the control treatment and treatments that received later applications of fertilizer were shorter than those that received fertilizers at transplanting. Treatments had highly significant effects on the number of tillers per hill at this time. The highest number of tillers were found in plants that received nitric phosphate at transplanting. This effect, however, did not last during the rest of the growing season for the number of tillers per hill in this treatment was seen to diminish in comparison to those of other treatments.

At 42 days from transplanting, as expected, the tallest plants were observed in treatment 7 which received 120 Kg N per hectare and the shortest plants were observed in the control treatment. This trend was seen at 123 days (at final harvest). It is also this treatment that had the significantly highest number of tillers per hill at 42 and 123 days from transplanting. From the data on grain yield in Table 7 it is seen that this treatment was significantly better than all other treatments and the greater height and greater number of tillers per plant appears to be directly related to grain yield under conditions that existed during this experiment. Generally however, taller plants would be more susceptible to lodging ; and lodging particularly in the early stages could be detrimental to yield. The next best treatment as judged by plant height and tiller numbers was observed in plots where ammonium sulphate was applied in rows at transplanting at 5 cm. depth (Treatment 1). Broadcast application of ammonium sulphate (and superphosphate) 2 weeks before primordial initiation produced relatively shorter plants with lesser number of tillers per plant (Treatment 4).

Dry Matter Production

The effect of treatments on total dry matter production is seen from the data in Table 6.

It will be noted that, among treatments 1 to 6, high amounts of dry matter were produced during the first 42 days of growth from transplanting in plots fertilized with ammonium sulphate (and superphosphate) and ammophos-B at planting in rows at 5 cm. depth. The smallest amount of dry matter produced during this period of growth was in plots fertilized with nitric phosphate 2 weeks before primordial initiation.

At the final harvest, 123 days from transplanting it was found that plants in treatment 7 which received 120 Kg N per hectare had a very significantly higher content of dry matter than any other treatment. This was as expected. The data in Table 7 indicates that excessive dry matter production had no adverse effect on grain yields. On the contrary this treatment showed a highly significant increase in grain yield over other treatments.

Effect of Treatments on Grain Yield and Yield Components

The effect of fertilizer treatments on grain yield and yield components is seen from the data in Table 7.

Yield of Filled Grain

The effect of treatments on grain yields was significant at the 1 per cent. level of probability. The highest yield of filled grain was in treatment 7 where ammonium sulphate was applied at the rate of 120 Kg N per hectare in rows at 5 cm depth and superphosphate was applied at the rate of 60 Kg P_2O_5 per hectare, broadcast on the surface at transplanting. The additional 67 Kg N per hectare gave a yield increase of 880 Kg grain per hectare over the next highest yield which received 53 Kg N per hectare in three split applications (treatment 8) which is the fertilizer recommendation of the Department of Agriculture for the area. It is noteworthy that treatment 8 which received only 53 Kg N per hectare, 33 Kg P_2O_5 per hectare and 31 Kg K_2O per hectare out-yielded treatments that received more nitrogen per hectare in a single application, with the exception of treatment 7 thus indicating a positive advantage in split application of nitrogen fertilizers on these soils.

Comparison of yield data in treatments 9, 1 and 7 shows the response to 60 and 120 Kg N per hectare supplied as ammonium sulphate was 634 and 1,533 Kg filled grain per hectare respectively. Comparison of yield data in treatments 10 and 9 show that the response to 60 Kg per hectare each of P_2O_5 and K_2O is 342 Kg filled grain per hectare.

The data on grain yield also shows no significant differences between treatments 1 and 4, 2 and 5 or 3 and 6 indicating that application of all the nitrogen and phosphorus at transplanting or 2 weeks before primordial initiation had the same effect under the conditions of this experiment. However, it should be noted that except for the ammonium sulphate-superphosphate mixture, later application of nitrogen and phosphorus produced more grain, although the differences did not reach statistical significance.

The effect of treatments on yield of filled and unfilled grain was highly significant. The yields of total grain follow the same pattern as that of filled grain in most treatments.

Number of Panicles Per Hill

The effect of treatments on the number of panicles per hill was highly significant. Plants that received 120 Kg N per hectare applied in rows at 5 cm depth (Treatment 7) had a significantly higher number of panicles than any other treatment. Plants treated with the nitric phosphate fertilizers had lesser number of tillers than those treated with ammonium sulphate and ammophos-B. Plants in plots where no fertilizer was applied (Treatment 10) had the least number of panicles per hill.

Panicle Weight, Weight Per 1,000 Grains and Percentage Ripened Grain

Treatments had no significant effect on yield components such as the weight per panicle, weight per 1,000 grains or on the percentage ripened grains (Table 7).

Grain : Total Dry Matter Ratio %

There were highly significant effects of fertilizer treatments on the grain : total dry matter ratio in plants (Table 7). This ratio was least in treatment 7 that received 120 Kg N per hectare and highest in treatment 9 which received only phosphorus and potassium but no nitrogen.

Grain : Straw Ratio

The grain : straw ratio of the differently fertilized plots generally followed the same trends as the grain : total dry matter ratio and showed differences that were highly significant.

CONCLUSIONS

Early application of nitrogen fertilizers caused greater uptake of nitrogen from a fertilizer than a late application. The combined nitrogen and phosphorous fertilizers ammophos-B and nitric phosphate, were both inferior to the combination of ammonium sulphate and super-phosphate as far as grain yields were concerned. Ammonium sulphate and ammophos-B are better sources of nitrogen than nitric phosphate as judged by plant uptake.

The percentage of phosphorus derived from fertilizer from all sources is greater when applied at transplanting than at 2 weeks before primordial initiation.

It is noteworthy that fertilizer applications according to the recommendations of the Department of Agriculture gave higher grain yields than all other treatments that received more nitrogen and phosphorus with the exception of that which received 120 Kg N per hectare. The economics of fertilizer use cannot be worked out because costs of all fertilizers are not known.

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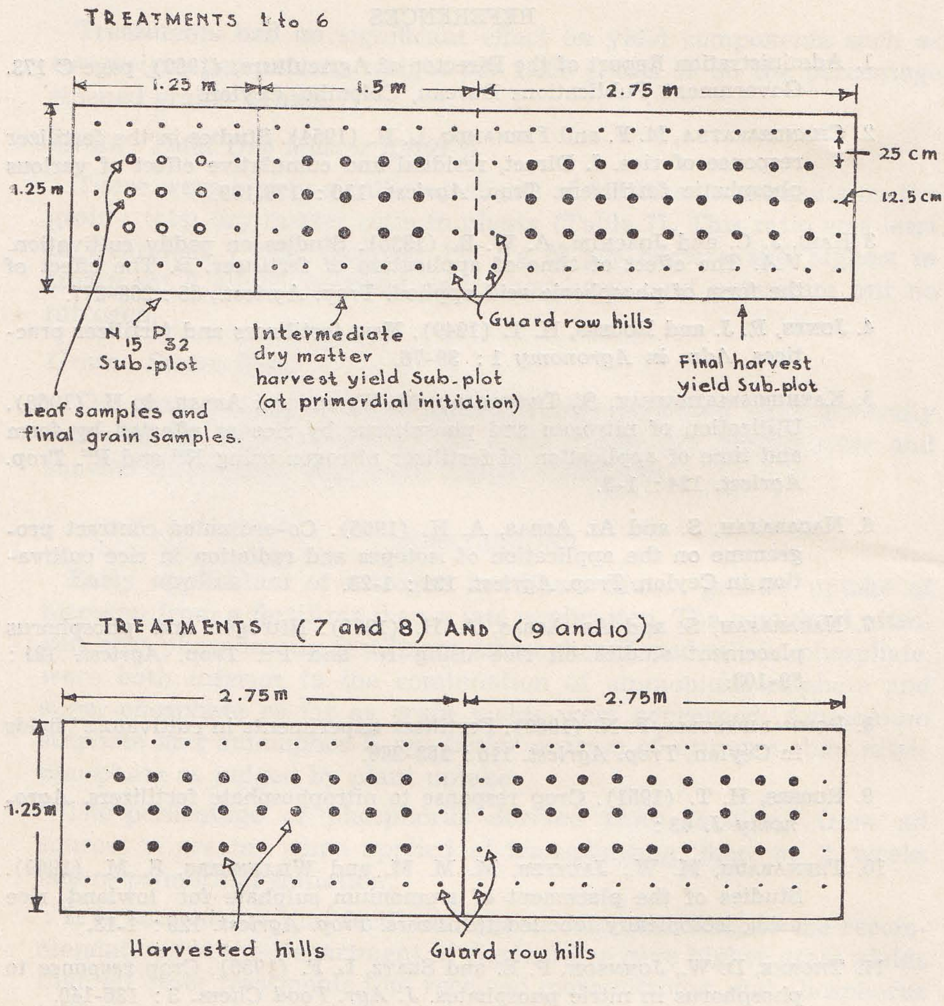

FIG 1. Single plot diagrams showing division into sub.plots, number of hills and their time of harvest

Table 1.—Characteristics of the Soil at Location of Experiment (Maha-Illuppallama)

Depth (cm.)	0–20	20–40
Texture	Sandy Loam	Sandy Loam
pH (1 : 1—Soil : H_2O)	5·9	6·0
E. C. (1 : 5—Soil : H_2O) (m.mhos/cm.)	0·1666	0·1242
Organic Matter %	2·37	2·01
Total Nitrogen %	0·1361	0·1052
Available P^2O^5 (Olsen's) (lbs. P^2O^5/acre)	29·1	20·5
Cation Exchange Capacity (m.e./100 g.)	14·8	13·6
Exchangeable Cations (m.e./100 g.)—		
Calcium	6·01	5·83
Magnesium	4·67	4·48
Potassium	1·03	0·80
Sodium	0·34	0·27
Total Exchangeable Bases (m.e./100 g.)	12·23	11·59

Table 2.—Mean Monthly Climatological Data from Nursery to Harvest

	Temperature (°F)		*Wind (m.p.h.) (6ft.)*	*Sunshine (hrs./day)*	*Rainfall (inches)*
	Maximum	*Minimum*			
May	90·2	76·7	2·92	—	3·35
June	90·8	76·4	2·54	8·3	0·86
July	90·4	76·6	3·62	7·5	0·24
August	92·4	76 3	3·96	8·6	0·16
September	93·2	75·4	3·58	8·3	1·26

Table 3.—Effect of Treatments on Utilization of Nitrogen from Feritilizer by Plants (% N Derived from Fertilizer)

(Mean of Four Replicates)

Days from transplanting Treatments	*Leaf Tissue*			*Grain*	*Straw*
	20	*42*	*72*	*123*	*123*
1. Ammonium sulphate (5 cm. depth in rows) and super phosphate broadcast at transplanting	61·2	57·0a*	36·8a**	17·0ab*	21·2
2. Ammophos B (5 cm. depth in rows) at transplanting	70·2	55·7a	37·0a	24·8a	55·9
3. Nitric phosphate (5 cm. depth in rows) at transplanting	63·8	38·8bc	18·9b	15·4bc	10·5
4. Ammonium sulphate and superphosphate broadcast 2 weeks before primordial initiation	—	52·0ab	25·4ab	18·3ab	14·7
5. Ammophos B broadcast 2 weeks before primordial initiation	—	48·6abc	24·0ab	15·4bc	12·4
6. Nitric phosphate broadcast 2 weeks before primordial initiation	—	36·4c	16·2b	9·1c	10·4
Coefficient of variation (%)	10·74	20·43	24·23	30·63	—

*Significant at the 5% level using Duncan's Multiple Range Test.

†Significant at the 1% level using Duncan's Multiple Range Test.

Means not followed by the same letter within a column are significantly different from each other.

Table 4.—Effect of Treatments on Utilization of phosphorus from Feritilizer by Plants (Mean of Four Replicates)

Days from transplanting *Treatments*	*%in Leaf Tissue*		*%derived from Fertilizer*	
	20	*42*	*20*	*42*
1. Ammonium sulphate (5 cm. depth in rows) and super phosphate broad-cast at transplanting	0·239a*	0·208abc**	44·4	37·4ab**
2. Ammophos B (5 cm. depth in rows) at transplanting	0·246a	0·183c	69·2	44·8a
3. Nitric phosphate (5 cm. depth in rows) at transplanting	0·214b	0·193bc	54·0	45·lab
4. Ammonium sulphate and super phosphate broadcast 2 weeks before primordial initiation	—	0·213abc	—	25·4bc
5. Ammophos-B broadcast 2 weeks before primordial initiation	—	0·229a	—	28·7bc
6. Nitric phosphate broadcast 2 weeks before primordial initiation	—	0·218ab	—	17·4c
Coefficient of variation (%)	4·32	7·37	24·54	18·61

*Significant at the 5% level using Duncan's Multiple Range Test.

**Significant at the 1% level using Duncan's Multiple Range Test.

Means not followed by the same letter within a column are significantly different from each other.

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Table 5.—Effect of Treatments on Plant Height and Number of Tillers Per Hill (Mean of Four Replicates)

Days from Transplanting Treatments	Plant Height (cm.)			Number of Tillers Per Hill		
	14	42	123	14	42	123
1. Ammonium sulphate (5 cm. depth in rows) and Superphosphate broadcast at transplanting	48.2ab**	80.7bc**	128.5b**	4.8ab**	20.7b**	14.5b**
2. Ammophos-B (5 cm. depth in rows) at transplanting	49.1a	78.5bcd	123.4bcd	4.2abc	19.6bc	13.9bc
3. Nitric phosphate (5 cm. depth in rows) at transplanting	48.4ab	72.9cde	118.9cd	5.2a	15.55de	13.5bc
4. Ammonium sulphate and Superphosphate broadcast 2 weeks before primordial initiation	44.0abc	80.0bc	125.2bc	3.5bc	17.5bcd	13.4bc
5. Ammosphos B broadcast 2 weeks before priomordial initiation	43.0c	83.9b	124.3bcd	3.2bc	19.5bc	14.3b
6. Nitric phosphate boradcast 2 weeks before primordial initiation	43.4bc	70.5def	120.5cd	3.4bc	16.5cde	12.0cd
7. Ammonium sulphate @ 120 Kg. N/ha (5cm. depth in rows) and Superphosphate broadcast at transplanting	48.6ab	102.2a	136.9a	4.6abc	26.5a	16. 7a
8. Recommendations of the Department of Agriculture for the area	44.4abc	65.6ef	130.0ab	3.4bc	13.8ef	12.1cd
9. No nitrogen, only Superphosphate broadcast at transplanting	43.4bc	62.7f	116.5d	3.4bc	13.8ef	12.2cd
10. Control (zero N, P_2O_5 and K_2O)	41.4c	64.0f	117.3cd	3.1c	12.0f	10.9d
Coefficient of variation (%)	5.29	5.35	3.02	19.69	9.16	6.89

**Significant at the 1% level using Duncan's Multiple Range Test.

Means not followed by the same letter within a column are significantly different from each other.

Table—6

Effect of Treatments on Dry Matter Production—

(Mean of four Replicate)
(Kg./ha)

	Treatments	*60 Day Early Harvest (42 days from transplanting)*	*Final Harvest (123 days from transplanting*
1.	Ammonium sulphate (5 cm. depth in rows) and superphosphate broadcast at transplanting	2460.0a**	12659.3b**
2.	Ammophose–B (5 cm. depth in rows) at transplanting	2316.5a	10757.5bcd
3.	Nitric phosphate (5 cm depth in rows) at transplanting	1746.5ab	9275.5d
4.	Ammonium sulphate and superphosphate broadcast 2 weeks before primordial initiation	1883.5ab	12254.0bc
5.	Ammophos–B broadcast 2 weeks before primordial initiation	1826.0ab	11758.8bc
6.	Nitric phosphate broadcast 2 weeks before primordial initiation	1256.8b	10130.5cd
7.	Ammonium sulphate at 120 Kg. N/ha, (5 cm. depth in rows) and Superphosphate broadcast at transplating	—	18436.0a
8.	Recommendations of the Department of Agriculture for the area	—	10524.8bcd
9.	No nitrogen, only superphosphate and muriate of potash broadcast transplanting	—	9099.8d
10.	Control (zero N, P_2O_5 and K_2O	—	8891.0d
	Coefficient of variation (%)	17.93	9.06

**Significant at the 1% level using Duncan's Multiple Range Test. Means not followed by the same letter within a column are significantly different from each other.

Table 7.—Grain Yield and Yield Components as affected by Treatments (Mean of Four Replicates)

	Grain Filled) (Kg./ha.)	*Grain (Filled & unfilled) (Kg./ha)*	*Panicles Per Hill*	*Pincle Weight (gm.)*	*Weight 1000 Grains (gm.)*	*Percentage Ripened grains*	*Grain / Total Dry matter(%)*	*Grain / Straw*
1. Ammonium sulphate (5 cm. depth in rows) and superphosphate broadcast at transplanting	5884.8b**	6164.5bc**	13.5b**	3.28	26.50	94.4	53.2bc**	1.236bcd**
2. Ammophos —B(5 cm. depth in rows) at transplanting	5435.5bc	5681.5bcd	12.7bcd	3.02	27.02	95.1	52.8bc	1.219cd
3. Nitric phosphate (5 cm. depth in rows)at transplanting	4916.8c	5152.5d	11.8bcde	2.74	26.92	95.3	55.6abc	1.379abcd
4. Ammonium sulphate and superphosphate broadcast 2 weeks before primordial initiation	5675.5bc	5963.0bcd	12.4bcd	3.25	26.92	95.2	48.9c	1.036d
5. Ammophos-B broadcast 2 weeks before primordial initiation	5666.8bc	5964.5bcd	13.2bc	3.08	27.04	94.8	50.7c	1.108d
6. Nitric phosphate broacast 2 weeks before primordial initiation	4985.0bc	5294.8cd	11.1dc	3.01	27.17	92.3	52.8bc	1.226bcd
7. Ammonium sulphate @ 120 kg. N/ha. (5cm. depth in rows) and superphosphate broadcast at transplanting	6783.8a	7062.0a	15.8a	2.96	26.58	95.7	38.5d	0.659e
8. Recommendations of the Department of Agriculture for the area	5903.5b	6205.8b	11.5cde	3.43	26.53	95.5	59.0ab	1.634ab
9. No nitrogen, only superphosphate and muriate of potash broacast at transplanting	5250.5bc	5530.3bcd	11.0de	3.29	26.98	93.0	60.9a	1.749a
10. Control (zero N, P_2O_5 and K_2O)	4908.0c	5229.5d	10.3e	3.26	26.52	96.1	58.7ab	1.587abc
Coefficient of variafation (%)	7.74	7.06	6.85	9.73	2.23	2.71	6.07	15.24

**Significant at the 1% level using Duncan's Multiple Range Test.

Means not followed by the same letter within a column are significantly different from each other.

Experiments with granular-compound-fertilizers on rice in the dry-zone of Ceylon

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SUMMARY

Experiments conducted in the wet-zone of Ceylon indicated that for rice granular-compound-fertilizers were superior to straight fertilizers. Similar investigations conducted in parts of the dry-zone indicate that granular-compound-fertilizers are not superior to straight fertilizers at all locations tested. In some locations straight fertilizers applied according to recommendations of the Department of Agriculture are as good as granular-compound-fertilizers.

INTRODUCTION

Granular-compound-fertilizer have several advantages over "simple" or "straight" fertilizer which contain one or more plant nutrients. Granulation or pelletization of fertilizer mixtures prevents the segregation in the bag of the individual constituents of a fertilizer mixture. Segregation takes place during handling and transportation specially if crystalline fertilizers like ammonium sulphate are mixed with finely powdered fertilizers like rock phosphate (saphos phosphate). Granular fertilizers are easy to handle and enable the uniform application of balanced quantities of nutrients in the field. They can be broadcast uniformly unlike finely ground powders which tend to be blown away by wind or carried away by water. A further advantage of these granular fertilizers is that they cannot be easily adulterated.

Experiments carried out at research stations, farms and in cultivators' fields of the wet-zone have shown that granular-compound-fertilizers are generally more efficient sources of nutrients for rice than simple straight fertilizers (4). This paper reports the results and conclusions of experiments using granular-compound-fertilizers on rice conducted in several locations in the dry-zone. A single experiment conducted in one location of the intermediate-zone (Nalanda) is also included.

The agro-climatic zone designated as the dry-zone consists of the lowland plains of the north and east of the island where the annual rainfall is between 50 and 75 inches. According to Panabokke and

Nagarajah (3) some of the best rice growing soils of the dry-zone occur in the flood plains of the major rivers and streams. Most rice-growing soils of the dry-zone are moderately fine textured, but those in some parts of the Trincomalee, Batticoloa and Amparai districts are coarse textured.

EXPERIMENTAL

The components and composition of the granular-compound-fertilizers used were as follows :—

Fertilizers	*Components*	*Composition* *N%*	*P_2O_5%*	*K_2O1%*	*MgO%*
1. Sunfoska A	$(NH_4)_2HPO_4$ $(NH_4)_2SO_4$ Urea KCL	15	15	15	—
2. Sunfoska B	$(NH_4)_2HPO_4$ $(NH_4)_2SO_4$ NH_4CI KCL Mg $(OH)_2$ H_3PO_4	15	15	6	4
3. Ammonium Phosphate Type	$(NH_4)_2HPO_4$ Conc. Superphosphate KCI	5	15	15	—
4. I. B. Compound	Isobutylidene diurea Conc. Superphosphate Fused Magnesium Phosphate KCL	10	10	10	1
5. Ammonium Chloride Type	NH_4CL $(NH_4)_2HPO_4$ KCL	14	14	14	—

A. In the first set of experiments conducted in the dry-zone during the Yala season of 1967 efficiencies of 15–15–15 ; N-P_2O_5-K_2O and 15-15-6-4 ; N-P_2O_5-K_2O-MgO were compared with straight fertilizers applied according to the recommendations of the Department of Agriculture. These experiments were conducted at the following locations :—

(1) Amparai district, where experiments were conducted in cultivators' fields at Annamalai, Central Camp and Uhana.

(2) Polonnaruwa district, where experiments was conducted at eight locations in cultivators' fields and a replicated experiment was conducted at the Seed Paddy Station, Hingurakgoda.

(3) Rice Research Station, Nalanda, of the Intermediate Zone.

The treatments were as follows :—

(1) No fertilizers.

(2) Straight fertilizers applied according to recommendations of the Department of Agriculture ;

(3) Granular-compound-fertilizer (15-15-15 ; N-P_2O_5-K_2O) at 300 lbs. per acre applied before planting.

(4) Granular-compund-fertilizer (15-15-15 ; N-P_2O_5-K_2O) at 300 lbs. per acre applied one week after planting or four weeks after sowing.

(5) Granular-compound-fertilizer (15-15-6-4; N-$P_2O_5K_2O$-MgO) at 300 lbs. per acre applied before planting.

(6) Granular-compound-fertilizer (15-15-6-4 ; N-P_2O_5-M_2O) at 300 lbs. per acre applied one week after planting or four weeks after sowing.

In the Amparai district the variety H_4 was used at all three locations. In cultivators' fields of the Polonnaruwa district the variety H_7 was used in six locations and the varieties H_4 and Pachchaiperumal were used in the other two locations. The variety H_4 was also used at the Seed Paddy Station, Hingurakgoda and at the Rice Research Station, Nalanda.

B. In the second set of experiments conducted in the dry-zone during Maha 1967–68 the same fertilizers as above were tested in the Polonnaruwa district at two locations, viz. the Polonnaruwa Farm and at the Seed Paddy Station, Hingurakgoda. The treatments were the same as above with the exception of the quantity and form of phosphorus fertilizers in treatment 2, where straight fertilizers were applied according to recommendations of the Department of Agriculture. This change in phosphorus fertilizer was in accordance with the recommendations for rice by the Department of Agriculture which were effective from September, 1967(I). The variety H_4 was used at all locations.

C. The efficiencies of five granular-compound-fertilizers were evaluated in field experiment during Maha 1967–68 in a Cultivators' field at Galgamuwa (Embogama), at the Dry-Zone Research Station, Maha-Illuppallama and at the Government Farm, Karadian Aru. The treatments were as follows :—

(1) Straight fertilizers applied according to recommendations of the Department of Agriculture.

(2) Granular-compound-fertilizer (15-15-15 ; N-P_2O_5-K_2O) at 300 lbs. per acre applied before planting.

(3) Granular-compound-fertilizer (15-15-6-4 ; N-P_2O_5-K_2O-MgO) at 300·lbs. per acre applied before planting.

(4) Granular-compound-fertilizer (15-15-15 ; $N-P_2O_5-K_2O$) at 300 lbs. per acre applied before planting and 30 lbs. nitrogen per acre in the form of straight fertilizer applied at pollen-mother-cell stage.

(5) Granular-compound-fertilizer 10-10-10 ; $N-P_2O_5-K_2O$ (I.B. Compound) at 450 lbs. per acre applied before planting.

(6) Granular-compound-fertilizer 14-14-14 ; $N-P_2O_5K_2O$ (Ammonium cloride type) at 321 lbs. per acre applied before planting.

The variety H-4 was used at all locations.

RESULTS AND DISCUSSION

A. The results of field experiments conducted in the Amparai and Polonnaruwa districts and at the Rice Research Station, Nalanda, during Yala 1967 are presented in Table 1.

Amparai District

The need for fertilizer application every season at these three locations is apparent from the relatively low yields obtained in the control treatments which received no fertilizers.

At Annamalai the yields of paddy due to treatments were not significantly different from each other. However, the highest yield was obtained in plots treated with straight fertilizers according to recommendations of the Department of Agriculture. At Central Camp the treatment which received straight fertilizers applied according to recommendations of the Department of Agriculture gave a significantly higher yield than the control treatment and the treatments that received the granular-compound-fertilizers 15-15-15: $N-P_2O_5-K_2O$ and 15-15-6-4 : $N-P_2O_5-K_2O-MgO$. At this location application of granular-compound-fertilizers before planting gave more yield than application after planting though the difference did not reach statistical significance. At Uhana the granular-compound-fertilizer treatments were not significantly different from each other or from the straight fertilizer treatment applied according to the recommendations of the Department of Agriculture. Here too like at Annamalai and Central Camp, the highest yield of paddy was when straight fertilizers were applied according to recommendations of the Department of Agriculture where nitrogen was supplied in three split application; at tillering, at heen-bundi and at heading while the phosphorous and potassium were applied before planting.

From the above findings it could be concluded that at these locations straight fertilizers applied according to recommendations of the Department of Agriculture are as good as or better than granular-compound-fertilizers supplying the same nutrients. At Central Camp the former was significantly better than the latter. As indicated in Table 1 the recommendations of srraight fertilizers in the Amparai district supplies two pounds more of nitrogen per acr than that supplied by the granular-compound-fertilizers. However, the amounts of phosphorus and potassium supplied in the straight fertilizer treatment were less than that of the granular-compound-fertilizer treatment by and 17 lbs. P_2O_5 and K_2O per acre respectively. It should also be noted that the form of phosphorus in the straight fertilizers applied according to the recommendations of the Department of Agriculture had the water insoluble rock phosphate (Saphos phosphate) while the granular-compound-fertilizers used had the water soluble di-ammonium phosphate.

Comparison of the yield data in treatments 3 and 4 with those of treatments 5 and 6 indicate that there was no drastic reduction in yield due to the smaller quantity of K_2O supplied in the latter treatments which received only 18 lbs. K_2O per acre in contrast to 45 lbs. K_2O per acre in the former treatments.

Polonnaruwa district

In the cultivators' fields of the district there were no significant differences in grain yield between straight fertilizers applied according to recommendations of the Department of Agriculture and either of the two granular-compound-fertilizers (15-15-15,N-P_2O_5 K_2O or 15-15-6-4 ; N-P_2O_5-K_2O-MgO). The control treatment that received no fertilizers gave a significantly lower yield than those receiving granular-compound-fertilizers or straight fertilizers emphasising the need for fertilizer applications every season.

At the Seed Paddy Station, Hingurakgoda, application of granular-compound -fertilizers 15-15-15 ; N-P_2O_5-K_2O one week after planting gave a significantly higher yield over straight fertilizers applied according to recommendations of the Department of Agriculture. The other treatments receiving granular-compound-fertilizer were however, not significantly different from the straight fertilizer treatment. As in the cultivators' fields the significantly different low yield in the control treatment reflects the need for the application of fertilizers every season.

As in the Amparai district, straight fertilizers applied according to the recommendations of the Department of Agriculture received two pounds more nitrogen per acre, but received 2 lb. less phosphorus and potassium, the difference being 14 lbs. P_2O_5 and 17 lbs. K_2O per acre (Table 1). Further, the form of phosphorus was saphos phosphate in the straight fertilizer treatment in contrast to di-ammonium phosphate in the granular-compound-fertilizer.

Comparison of the yield data from the granular-compound-fertilizers treatments (3, 4, 5 and 6) shows that reducing the content of K_2O from 45 to 18 lbs. per acre did not appear to generally reduce yields of grain in cultivators' fields or at the Seed Paddy Station, Hingurakgoda.

Rice Research Station, Nalanda

There were no significant differences, in yield of grain, due to treatments at this Station, although the highest yield was obtained with straight fertilizers

B. The effect of treatments on grain yields in experiments conducted during Maha 1967/68 in the Polonnaruwa district are presented in Table 2.

It will be observed that treatments receiving the two granular-compound-fertilizers 15-15-15; N-P_2O_5-K_2O and 15-15-6-4 ; N-P_2O_5-K_2O-MgO yielded more than those receiving straight fertilizers applied according to recommen dations of the Department of Agriculture for the district at both stations. The unfertilized plots had significantly lower yields than any of the fertilized plots indicating the need for fertilizer applications every season.

From information furnished at the bottom of Table 2 it would be noted that the treatment receiving straight fertilizers received 2 and 3 lbs. of nitrogen and phosphorus respectively more than any of the treatments receiving granu-compound-fertilizers.

C. The effects of fertilizer treatments on grain yield in experiments conducted at Galgamuwa, Maha-Illuppallama and Karadian Aru during Maha 1967/68 are presented in Table 3.

At Galgamuwa the differences due to treatment were significant. Straight fertilizers applied according to recommendations of the Department of Agriculture were found to be inferior to all granular-compound-fertilizers tested at this location except the fertilizer 15-15-6-4 ; N-P_2O_5-K_2O-MgO. It should be noted that the straight fertilizer treatment received 2 lbs. extra nitrogen per acre in comparison to the compound fertilizer treatment (Table 3).

At Maha-Illuppallama and Karadian Aru the effects of treatments on grain yields were not significant. It will be noted, however, that at Karadian Aru the treatment where straight fertilizers were applied according to recommendations of the Department of Agriculture yielded the highest. In this treatment nitrogen was given in split applications. Another noteworthy point is that the straight fertilizer treatment received only 28 lbs. per acre of K_2O in contrast to 45 lb. per acre which all other treatments received except that receiving the granular-compound-fertilizer 15-15-6-4 ; N-P_2O_5-K_2O-MgO. This together with the fact that yields in the treatment that received the granular-compound-fertilizer 15-15-6-4; N-P_2O_5-K_2O-MgO were not significantly different from the treatment that received 45 lbs. K_2O per acre in the form of other granular-compound-fertilizers indicated that 28 lbs. K_2O per acre would be sufficient to obtain optimum yields of paddy with the variety used (H-4) at the levels of nitrogen and phosphorus applied.

ECONOMICS OF FERTILIZER USE

The economics of the use of granular-compound-fertilizers for some locations in the dry zone are presented in Tables 4, 5, 6 & 7. Only locations that showed significant differences in yields due to treatments have been considered. The price of paddy was taken at Rs. 14 per bushel. The cost of fertilizers were calculated from C.I.F. values furnished by the Ceylon Fertilizer Corporation as follows :—

Ammonium Sulphate	Rs. 300 per ton
Saphos phosphate	Rs. 173 per ton
Concentrated Super phosphate	Rs. 390 per ton
Muriate of potash (50% grade)	Rs. 245 per ton
Granular-compound-fertilizers 15-15-15 : N-P_2O_5-K_2O ; 15-15-6-4 : N-P_2O-K_2O-MgO and 5-15-15 : N-P_2O_5-K_2O at	£ 30 per ton

Total net income is the difference between the value of the paddy obtained from a treatment and the cost of the fertilizer. Net return is the difference between the value of yield increase due to fertilizer application and cost of the fertilizer applied. It will be noted that the yield increases shown in tables 4, 5/4, 5, 6 and 6 are calculated relative to thecontrol treatment that received no fertilizer while in table 7 the yield increases from granular-compound-fertilizers are calculated relative to the straight fertilizer treatment.

A limitation in these calculations is that only the cost of the fertilizer is deducted from the value of the yield increase to obtain net returns, and other expenditure such as labour, costs of seed paddy and agro-chemicals, etc. are not considered. Therefore the figures for net returns are not absolute and only show relative values.

It will be observed that at Central Camp and Uhana of the Amparai district the highest net return was obtained from the use of straight fertilizers applied as recommended by the Department of Agriculture (Table 4). It should be noted, however, that only at Central Camp was the yield due to the straight fertilizer treatment significantly better than any of the granular-compound-fertilizer treatments. From the above it is clear that the application of the more expensive granular-compound-fertilizers is not economical when compared with straight fertilizers applied according to recommendations of the Department of Agriculture at these two locations. It should also be remembered that the straight fertilizer treatment yielded the highest even at Annamalai (Table 1), but this data is not discussed here as yield differences were not significant among treatments.

The results from eight locations in cultivators' field of Polonnaruwa district and from the Paddy Station, Hingurakgoda during Yala 1967 show that the highest net return was obtained from the treatment where the granular-compound-fertiizer 15-15-15 ; N-P_2O_5-K_2O was applied after planting or sowing (Treatment 4). In the cultivators' fields there was a gain of Rs. 28.38 in treatment 4 over the straight fertilizer treatment, but from table 1 it will be observed that the differences in yield of paddy between these treatments were not significant. At the Seed Paddy Station, Hingurakgoda however, treatment 4 was significantly better than the straight fertilizer treatment and this accounts for a net gain of Rs. 76.03 from the application of the fertilizer 15-15-15 ; N-P_2O_5-K_2O one week after planting. (Table 5.)

Table 6 presents information on the economics of the use of granular-compound-fertilzers in experiments conducted during Maha 1967–68 at two locations (Polonnaruwa Farm and Seed Paddy Station, Hingurakgoda) in the Polonnaruwa district. In contrast to the net returns shown for Amparai and Polonnaruwa districts during the previous season (Tables 4, 5) it is seen here that granular-compound-fertlizers gave much higher net returns than straight fertilizers applied according to reocmmendations of the Department. However, it must be remembered that at these two locations yield differences between straight fertilizers applied according to recommendations of the Department of Agriculture and granular-compound-fertilizer were not always statistically significant as shown in Table 2 At the Polonnaruwa Farm only treatment 4 was significantly different from treatment 2 ; while at the Seed Paddy Station, Hingurakgoda only treatments 3 and 5 were significantly different from treatment 2

The economics of fertilizer use at Galgamuwa are presented in Table 7. If will be observed that yield increases and net returns from the use of granulatt compound-fertilizers are calculated relative to the straight fertilizer treatment and not relative to the no fertilizer control treatment as in Tables 4, 5 & 6. It will be observed that the greatest profit is obtained from the use or 15-15-15; N-P_2O_5-K_2O applied before planting

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TABLE 1.—Fertilizer Treatments and Yields of Paddy in Amparai and Polonnaruwa Districts and Rice Research Station, Nalanda Yala 1967

(Yield in bushels per acre)

Treatments	Amparai District: Annamalai	Amparai District: Central Camp	Amparai District: Uhana	Polonnaruwa District: Average of 8 locations in cultivator's field	Seed Paddy Station Hingurakgoda	Rice Research Station Nalanda
1. No fertilizer	34.3	52.9*a**	73.0*a*	42.7*a*	69.2*a*	81.8
2. Straight fertilizer applied according to recommendations of the Department of Agriculture†	48.4	78.1*b*	114.6*b*	60.1*b*	89.2*b*	89.4
3. Granular-compound-fertilizer (15–15–15) at 300 lbs. per acre applied before planting	42.3	64.6*a*	103.6*b*	62.3*b*	90.2*bc*	83.1
4. Granular-compound-fertilizer (15–15–15) at 300 lbs. per acre applied one week after planting or four weeks after sowing	46.6	58.7*a*	103.6*b*	62.8*b*	95.3*c*	73.2
5. Granular-compound-fertilizer (15–15–6–4) at 300 lbs. per acre applied before planting	38.0	64.1*a*	101.5*b*	60.4*b*	88.3*b*	71.3
6. Granular-compound-fertilizer (15–15–6–4) at 300 lbs. per acre applied one week after planting or four weeks after sowing	47.9	54.8*a*	100.8*b*	61.4*b*	93.8*bc*	84.2
Co-efficient of Variation	14.11%	11.13%	7.4%	16.63%	3.78%	12.17%

*Significant at 5% level using Duncan's Multiple Range Test (2).

Means not followed by same letter within a column are significantly different from each other.

†Recommendations of the Department of Agriculture were as follows :—*Amparai district :* 47 lbs. N, 24lbs. P_2O_5 and 28 lbs. K_2O ; *Polonnaruwa district & Nalanda :* 47lbs. N, 31 lbs. P_2O_5 and 28 lbs. K_2O as ammonium sulphate, saphos phosphate and muriate of potash respectively.

TABLE 2

Fertilizer Treatments and Yields of Paddy in the Polonnaruwa District—Maha 1967–68

(*Yield in bushels per acre*)

	Treatments	*Polonnaruwa Farm*	*Seed Paddy Station Hingurakgoda*
1.	No fertilizer	59.6*a** ..	65.8*a*
2.	Straight fertilizers applied according to recommendations of the Department of Agriculture† ..	82.6*b* ..	81.2*b*
3.	Granular compound fertilizer (15–15–15) at 300 lbs. per acre applied before planting	90.2*bc* ..	100.2*c*
4.	Granular-compound-fertilizer (15–15–15) at 300 lbs. per acre applied one week after planting ..	99.4*c* ..	87.5*bc*
5.	Granular-compound-fertilizer (15–15–6–4) at 300 lbs. per acre applied before planting	90.4*bc* ..	95.5*c*
6.	Granular compound-fertilizer (15–15–6–4) at 300 lbs. per acre applied one week after planting ..	96.3*bc* ..	89.2*bc*
	Co–efficient of Variation	11.29% ..	9.72%

*Significant at 5% level using Duncan's Multiple Range Test (2).

Means not followed by same letter within a column are significantly different from each other.

†Recommendation of the Department of Agriculture for Polonnaruwa District is 47 lbs. N, 48 lbs. P_2O_5 and 28 lbs. K_2O as ammonium sulphate, concentrated superphosphate and muriate of potash respectively.

TABLE 3

Fertilizer Treatments and Yields of Paddy at Galgamuwa, Maha-Illuppallama and Karadian Aru—Maha 1967-68

(*Yield in bushels per acre*)

Treatments	*Galgamuwa*	*Maha Illuppallama*	*Karadian Aru*
1. Straight fertilizers applied according to recommendations of the Department of Agriculture†	43.1*a**	137.1	81.5
2. Granular compound fertilizer (15–15–15) at 300 lbs. per acre applied before planting	65.4*c*	130.4	71.2
3. Granular-compound-fertilizer (15–15–6–4) at 300 lbs. per acre applied before planting	52.4*ab*	137.6	75.9
4. Granular compound-fertilizer (5,15-15) at 300 lbs. per acre applied before planting and 30 lbs. N per acre in the form of straight fertilizer applied at pollen-mother-cell stage	62.9*bc*	131.90	73.2
5. Granular-compound-fertilizer 10–10–10 (I.B. Compound) at 450 lbs. per acre applied before planting	62.5*bc*	148.0	80.3
6. Granular compound fertilizer 14–14–14 (Ammonium cholride type) at 321 lbs. per acre applied before planting	58.5*bc*	131.6	67.6
Co-efficient of Variation	9.85%	7.26%	10.87%

*Significant at 5% level using Duncan's Multiple Range Test. (2).

†Recommendations of the Department of Agriculture were as follows :

Galgammuwa : 47 lbs. N, 72 lbs. P_2O_5 and 28 lbs. K_2O per acre as ammonium sulphate conc. superphosphate and muriate of potash respectively.

Maha-Illuppallama : 47 lbs. N, 48 lbs. P_2O_5 and 28 lbs. K_2O per acre as ammonium sulphate concentrated superphosphate and muriate of potash respectively.

Karadian Aru : 51 lbs. N, 48 lbs. P_2O_5 and 28 lbs. K_2O per acre as urea concentrated superphosphate and muriate of potash respectively.

TABLE 4.—Economics of the use of Granular-compound Fertilizers 15–15–15 and 15–15–6–4 in the Amparai District, (Yala 1967)

Treat No.	Treatments	LOCATION: Ceutral Camp — Yield increase bu./acre	Ceutral Camp — Total net income Rs. c.	Ceutral Camp — Net return Rs. c.	Uhanv — Yield increase bu./acre	Uhanv — Total net income Rs. c.	Uhanv — Net return Rs. c.
1.	No fertilizers	—	740.60	—	—	1,022 0	—
2.	Straight fertilizers applied according to recommendations of the Department of Agriculture	25.20	1,050.70	310 10	41.60	1,561 70	539 70
3.	Granular-compound-fertilizer (15–15–15) at 300 lbs. per acre applied before planting	11.70	850.16	109 56	30.60	1,396 16	374 16
4.	Granular-compound-fertilizer (15–15£. 15) at 300 lbs. per acre pplied one weeks after planting or four weeks after sowing	5.80	767.56	26 96	30.60	1,396 16	374 16
5.	Granular-compound-fertilizer (15–15–6-4 at 300 lbs. per acre applied before planting	11.20	843.16	102 50	28.50	1,366 76	344 76
6.	Granular-compound-fertilizer (15–15–6–4) at 300 lbs.per acre applied one week after planting or four weeks after sowing	1,90	712,16	—	27,80	1,356 96	334 96

TABLE 5.—Economics of the use of Granular-Compound-Fertilizers 15–15–15 and 15–15–6–4 in the Polonnaruwa District (Yala 1967)

		LOCATION					
		Locations in Cultivators' Fields			*Seed Paddy Station, Hingurakgoda*		
Treat No.	*Treatments*	*Yield increase bu./acre*	*Total net income Rs. c.*	*Net return Rs. c.*	*Yield increase bu./acre*	*Total net income Rs. c.*	*Net return Rs. c.*
1.	No fertilizers	—	597 80	—	—	968 80	—
2.	Straight fertilizers applied according to recommendations of the Department of Agriculture	17 4	796 53	198 78	20.0	1,203 9	235 13
3.	Granular-compound-fertilizer (15–15–15) at 300 lbs. per acre applied before planting	19.6	817 96	220 16	21.0	1,208 56	239 76
4.	Granular-compound-fertilizer (15–15–15) at 300 lbs. per acre applied one week after planting or four weeks after sowing	20.1	824 96	227 16	26.1	1,279 96	311 16
5.	Granular-compound-fertilizer (15–15–6–4) at 300 lbs. per acre applied before planting	17.7	791 36	193 56	19.9	1,181 96	213 16
6.	Granular-compound-fertilizer (15–15–6–4) at 300 lbs. per acre applied one week after planting or four weeks after sowing	18.7	805 36	207 56	24.6	1,258 96	290 16

TABLE 6.—Economics of the Use of Granular-Compound Fertilizers in the Polonnaruwa District (Maha 1967/68)

LOCATIONS	*Polonnaruwa Farm*			*Seed Paddy Station Hingurakgoda*		
Treatments	*Yield increase Bu./acre*	*Total net income Rs. c.*	*Net return Rs. c.*	*Yield increase Bu./acre*	*Total net income Rs. c.*	*Net return Rs. c.*
1. No Fertilizer	—	834 40	—	—	921 20	—
2. Straight fertilizers applied according to recommendations of the Department of Agriculture	23.0	1,100 34	265 94	15.4	1,080 74	159 54
3. Granular-compound-fertilizer (15–15–15) at 300 lbs. per acre applied before planting	30.6	1,208 56	374 16	34.4	1,348 56	427 36
4. Granular-compound-fertilizer (15–15–15) at 300 lbs. per acre applied one week after planting	39.8	1,337 36	502 96	21.7	1,170 76	249 56
5. Granular-compound-fertilizer (15–15–6–4) at 300 lbs. per acre applied before planting	30.8	1,211 36	376 96	29.7	1,282 76	361 56
6. Granular-compound-fertilizer (15–15–6–4) at 300lbs. per acre applied one week after planting	36.7	1,293 96	459 56	23.4	1,194 56	273 36

Table 7. Economics of Fertilizer use at Galgamuwa (Maha 1967/68)

	Treatments	*Yield increase Bu/acre*	*Total net income Rs. c.*	*Net return Rs. c.*
1.	Straight fertilizers applied according to recommendations of the Department of Agriculture ..	—	538–03	—
2.	Granular-compound-fertilizer (15-15-15) at 300 lbs. per acre applied before planting ..	22.3	861–36	257–96
3.	Granular-compound-fertilizer (15-15-6-4) at 300 lbs. per acre applied before planting ..	9.3	679–36	75–96
4.	Granular-compound-fertilizer (5-15-15) at 300 lbs. per acre applied before planting and 30 lbs. N per acre in the form of straight fertilizer applied at pollen-mother-cell stage ..	19.8	826.36	222.96
5.	Granular-compound-fertilizer 10-10-10 (I.B. Compound) at 450 lbs. per acre applied before planting	19.4	820–76	217–36
6.	Granular-compound-fertilizer 14–14-14 (Ammonium chloride type) at 321 lbs. per acre applied before planting	15.4	764–76	161-36

A preliminary study of reproduction in the first batch of Jersey heifers gifted by New Zealand Government

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(Received June 1970.)

FOUR hundred and seventy five Jersey heifers and twenty five bull calves were gifted by the New Zealand Government to Ceylon in 1965. These animals (save one heifer which died on board during the journey) arrived by ship in Ceylon in June of the same year and formed the basis of the present 'New Zealand' Farm, Ambawela.

Soon after arrival in Ceylon they were transported by train to Ambawela. The pre-imunisation of these animals against Babesiosis and Anaplamosis were done immediately after their arrival in Ceylon.

The present 'New Zealand' Farm was at that time under construction and was to form another unit of the main farm at Ambawela. However, after the arrival and moving of these animals to this unit it was given the status of a separate farm. The animals being a gift from New Zealand the farm came to be known as the 'New Zealand' Farm, Ambawela and was distinct from the other farm at Ambawela which is composed of Ayrshires only. The material for this paper was obtained from the history sheets of the animals which were cows (360 cows) at the time of the study (July 1969). The purpose of the paper is to record the pattern of reproductive performance of these animals under our conditions though born in New Zealand.

Age at first calving: The early maturity of the Jersey breed is more marked than in any other breed. Rare cases have been reported of Jersey females having the first calf by the time they are a year old (Judkins and Keener 1965). As a breed both male and female develop rapidly. Some breeders today plan to have their heifers calve at about thirty months as they believe a greater vitality and producing capacity is secured. At Ambawela the initial breeding of the heifers was deliberately delayed and staggered as the buildings were not completed as anticipated and the extent of pasture lands was inadequate. This together with the fact that the exact date of birth of each animal was not known would not give an accurate value for the age at first calving. However, most animals were 6-8 months of age (Fonseka, 1969) though some were older and some were even pregnant on arrival here. In the light of the above the average age of 35 months as age at first calving obtained in this study is favourable, when compared with reported figures of 24-30 months for this breed in temperate countries (Juergensoo and Mortenson, 1964). A late age of first calving has also been observed with European cattle in high elevation areas in the tropics (Mahadevan, 1956).

Distribution of calvings.—Ten per cent. of the cows have had a single calf ; fifty six per cent. have had two calves and twenty four per cent. have had three calves. The average age of these animals being four years and eight months compares favourably with the distribution of calvings especially when considering the fact that some of them are again in various stages of pregnancy.

Twinning : The incidence of twinning is an uncommon feature (Rai, 1968). Two twin births have been observed out of all the births analysed, in one of these cases both were males.

Sex Ratio : Theoretically sex ratio should be 50 per cent. or 100 : 100. The reasons why it does not conform to this is not known. However, it is agreed that there is a higher percentage of males at conception than at birth. When only viable young are considered the ratio is in the region 95 : 100 (Branas *et al*, 1965). The sex ratio of viable calves at Ambawela Jersey Farm is in the region 93 : 100. A more accurate assessment of the ratio is possible if the number of births considered was large. The sex ratio of male calves usually varies from 42.6 to 53.7 per cent. (Roberts, 1961).

Calving interval : The calving interval is made up of the service period, or the period between parturition and subsequent conception and the period of gestation. The latter period is usually 284 × 4 days and the former between 60-90 days (Rai, 1968 ; Carmona and Monz, 1966). The Jersey cows as a breed could be expected to calve once a year for many years and it is not uncommon to find cows of twelve years and more as steady producers. The calving interval observed in the present study of the records was thirteen months (see Table 1). This is very close to the ideal of twelve months, however, it must be borne in mind that the service period in a sizeable number of animals was less than 60-90 days and this would have influenced the present value obtained.

Birth Weight: The birth weight of the calves born at the Jersey Farm, Ambawela did not show any significant difference between the sexes. The average birth weight iresspective of sex was 34 lbs. The Jerseys at Ambawela being smaller in confirmation than the American counterpart (whose birth weight varys from 45 lbs. to 75 lbs. Juerguson and Mortensen, 1960) and also in view of the local conditions prevailing at the time the average birth weight recorded is understandable. An increase could be expected in future years.

Lactation records: Fifty one percent of all the lactations studied was over 4000 lbs. while nineteen per cent were over 5000 lbs. The highest lactation recorded was 9000 lbs. The overall average of the lactations studied was 4049 lbs. (Lactations of 305 days only were considered). The lactation range is very variable in the breed and is influenced by a number of factors (Plumb, 1930).

Stillbirths, Abortions and Neonatael Mortality: The combined loss from these was observed to be ten per cent of all the births recorded. It was not possible to categorise individual causes. The losses sustained from these causes is low (Van Dieten, 1964).

Services per conception: An accurate estimate of the services per conception was not possible. From observations made the services per conception appears to be in the range 1.5 to 2.5, this range is suggestive of moderate fertility (Carmona and Monz, 1966).

INCIDENCE OF REPRODUCTIVE DISORDERS

Ovario-uterine hypoplasia, cystic ovaries, anoestrus and repeat breeding were the common causes of lowered fertility observed in some of the animals. The incidence of these was within the expected range (Riznov, 1967).

SUMMARY

A preliminary study of the pattern in reproductive performance of the Jersey animals gifted by New Zealand Government in 1965 was made. The age at first calving, distribution of calvings, twinning, sex ratio, calving interval, weight at birth, lactation, stillbirths, abortions neonatal mortality, services per conception and incidence of reproductive disoders were the aspects considered. The general performance of the animals from observations so far made has been good considering the factors and circumstances which influenced the

performance. With a more intense management and husbandry programme an improved performance could be expected. A comprehensive study will be possible with the accumulation of more data.

TABLE 1*

Number of cows	360
Number of heifers	67
Average age at 1st calving	35 months
Average weight at birth	34 lbs.
Sex ratio	93 100
Average calving interval	13 months
Twinning	2 pairs of twins (of all births)
Percentage cows with single calving	10%
Percentage cows with two calvings	56%
Percentage of still births abortions and neonatal mortality	10%
Highest lactation	9000 lbs.
Average lactation (305 day)	4049 lbs.
Lactation of 4000 lbs. and above	51%
Lactation of 5000 lbs. and above	19%

*Average values for characteristics studies.

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RESEARCH NOTE

A noteworthy new grass record for Ceylon

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PENNISETUM POLYSTACHYON (L.) Schult., Syst. Veg. Mant. 2 : 146, 1824. Based on *Panicum polystachyon* L., Syst. Nat. ed. 10, 2 : 870, 1759.

Robust *annual* (or sometimes perennial), 1.5-2.5 m. high ; culms softly herbaceous, usually branched from the upper nodes and sometimes also from the basal ones, terete or slightly compressed, glabrous, many-noded, the nodes glabrous ; leaf blades up to 30 cm. long (or more), flat or loosely folded, linear-lanceolate, long-acuminate with very fine points, pubescent with tubercle-based hairs ; leaf-sheaths rather loose on the culms, much shorter than the internodes, glabrous ; ligule long-ciliate, 1.5-2 mm. long ; collar narrowly membranous. *Spikes* golden-yellow in colour, prminently exserted, 17.5-20 cm. long, 3-4 cm. wide incl. bristles), 0.75-1 cm. wide (excl. bristles), compact, cylindric, continuous ; rhachis glabrous, straight or curved, with small decurrent wings on the ribs below the spikelets. *Spikelets* solitary, sessile ; callus very small, sparsely bearded, acute ; outer bristles 1.5-3.5 mm. long, scabrid ; inner bristles up to 2 cm. long, densely plumose in the lower part, scabrid, above. *Lower glume* suppressed. *Upper glume* thinly membranous, 5-nerved, oblong-elliptic, acute, cuspidate, scaberulous at the tip, glabrous. *Lower lemma* slightly shorter than the upper glume and similar in texture, broadly elliptic, acute, 3-toothed, scaberulous near the apex, otherwise smooth, 3 or sub-5-nerved ; palea absent. *Upper lemma* 2-2.5 mm. long, crustaceous, shiny, finely nerved, entire, narrow-elliptic ; the palea subequal to its lemma and similar in texture, embraced by the flattened margins of the lemma. *Caryopsis* 1-1.5 mm. long, oblong-elliptic, slightly compressed, subacute to obtuse, dull-brown ; embryo about half as long ; hilum subbasal.
2n-54 (Bor).

Though typically annual in habit, in favourable sites plants tend to behave as perennials, developing stout tussocks which persist for

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more than one season. From the upper nodes the culms usually branch strongly, producing numerous inflorescences and large quantities of grain, which observations indicate to be highly viable.

In Ceylon, plants of the species occur in a wide range of habitats and is now naturalized over extensive areas. Introduced probably with the grain of cereals or fodder grasses, this spontaneous introduction was first recorded for Ceylon at Melsiripura in 1966. Field observations show it to grow rapidly and vigorously, able to compete favourably with native grasses.

Distribution : The species is widespread in tropical regions of the Old World. In India, Bor (The Grasses of Burma, Ceylon, India and Pakistan, 1960) records it as an excellent fodder grass when young, also useful for hay making.

In Ceylon the centre of distribution appears to be the central uplands, from which the species has spread in all directions. In particular it has become well-established in the mid-uplands of adjacent wet zone provinces and is gradually invading the dry zone lowlands.

Economically, the species could be either useful or troublesome. In land under cultivation, particularly in the coconut fields, along the west and south of Ceylon, it could be a potentially serious weed, being coarse enough to hinder harvesting operations. In the dry zone lowlands where chena cultivation is practised, it would provide valuable fodder for stock if encouraged to replace the less palatable native grasses, which predominate after the initial disturbance of the scrubby forests.

Specimens examined : Kurunegala District ; Melsiripura, *Amaratunga, 1092,* 21 V. 1966. (This collection represents the first record for Ceylon). Matale District ; near Matale, *Lazarides 7217,* 5. IX. 1970. Amparai District ; 5 miles north-east of Inginiyagala on Mullagama track, *Lazarides 7251,* 10.IX.1970. Kurunegala District ; near Nikaweratiya, *Lazarides 7269,* 14.IX.1970. Puttalam District ; 8 miles north-east of Puttalam on Anuradhapura road, *Lazarides 7273,* 15.IX.1970.

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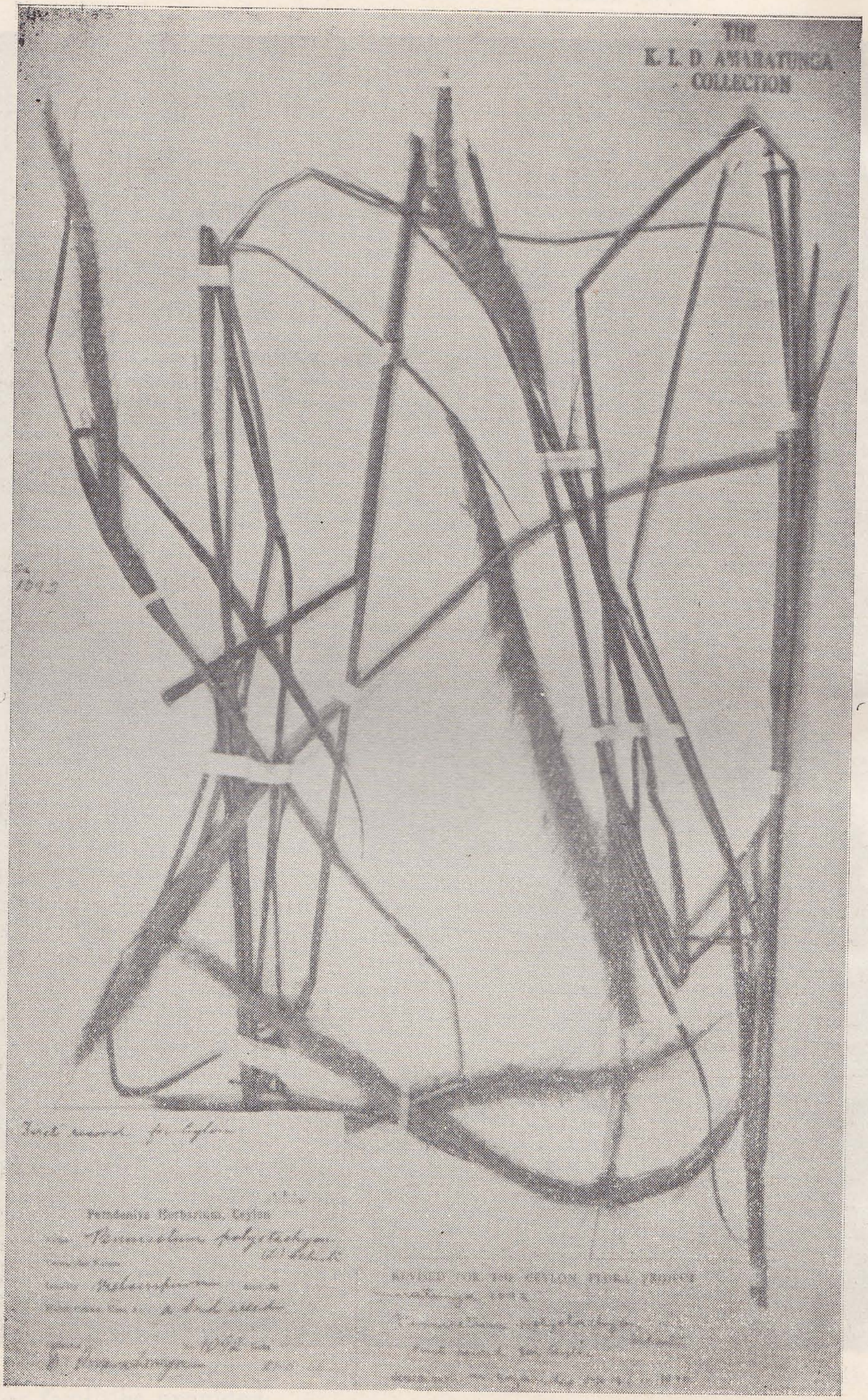
Field photograph of Pennisetum polystachyon near Inginiyagala, Amparai District



Photograph of Pennisetum polystachyon (Amaratunga 1092)

METEOROLOGICAL REPORT

QUARTERLY WEATHER SUMMARY—APRIL TO JUNE, 1970

APRIL : Intermonsoon weather conditions prevailed during most of April. Thunder activity was reported from some part or other of the Island, every day of the month. Isolated evening thundershowers were experienced during the first three days, a few very heavy falls being reported. On the 4th, the upper winds became more moist and moderate to fairly heavy rain, accompanied by thunder in places, was fairly widely experienced till the 7th. Except on the 12th and 13th, when rain was practically islandwide, thundershowers were less widespread from the 8th to the 26th and were confined chiefly to the central region of the Island and the southwest. However, from the 27th onwards, rain was again widely expereieced. A trough of low pressure caused moderatet to heavy rain in the south-west on the 29th.

The larger monthly totals of rainfall (totals over 25 inches) were over the Kegalla District Rainfall over the adjoining areas of the south-west quarter and parts of Uva ranged from 15 to 25 inches. Over the Southern Province the rainfall was mainly between 2 to 10 inches. In the Northern, North-central and Eastern provinces, rainfall was below 10 inches. Rainfall was above average over parts of the south-west quarter and Uva and at isolated stations in the north and east and in the North-Western Province. Day and night temperatures were generally a little above normal. Day humidity ranged from 62 to 81 per cent. while ight humidity ranged from 82 to 97 per cent. Mean cloud amounts and the mean air pressures were a little above normal. Wind mileages were below average, the direction being variable.

MAY : From the beginning of the month a south-westerly pressure gradient appeared on the charts, and this was in evidence throughout the month. The upper winds became southwesterly to a height of 20,000 feet under the influence of a low pressure area which developed in the Bay of Bengal on the 2nd. After this low pressure area moved away, the southwesterly wind stream became much shallower. During the rest of the month the southwesterly winds varied in dept and were over 10,000 feet (our criterion for the south-west monsoon) from the 9th to the 13th, on the 17th and 18th and again from the 23rd to the end of the month, mainly under the influence of low pressure areas in the neighbourhood of the Island. Temporary southwest monsoonal type weather conditions prevailed occasionally during the month. However, even at the end of May, the south-west monsoon wind stream had not been fully and finally established. This actually occurred only during the first week of June.

WEATHER : The low pressure area which formed in the Bay of Bengal on the 2nd resulted in tempporary south-west monsoon weather conditions, and moderate to very heavy rain was experienced in the south-west quarter that day, several falls of over 5 inches being recorded. Rainfall on the next two days was less heavy, only light to moderate falls being reported. Generally fair weather then prevailed from the 5th to the 7th. On the 8th, another low pressure area formed in South Bay of Bengal and deepening into a depression moved westwards and crossed the Indian coast near Tamilnadu on the 11th. During this period there was light to moderate rain in the south-west and among the central hills, with scattered thundershowers elsewhere. During the next few days up to the 16th, rainfall was mainly light. On the 17th, rain was widely experienced, several fairly heavy falls being reported. The rainfall on the 18th was less heavy and from the 19th to the 24th, scattered light to mederate rain was experienced mainly in the south-west quarter. A low pressure area developed in South-east Arabian sea on the 25th and rain was widely experienced over the Island. From the 26th to the end of the month, monsoonal type rain was experienced in the south-west quarter with scattered evening thundershowers over the North-central province.

The largest monthly totals of rainfall (totals over 30 inches) were over the Kalutara District. Rainfall over the adjoining south-western lowlands ranged from 20 to 30 inches decreasing to 2 to 10 inches over the central hills. Over the Northern, North-Central and Eastern Provinces, the rainfall was mainly below 5 inches. Rainfall was above average along the western coastal belt and a little above average over parts of the North-Centrtal and Eastern provinces. Rainfall was below aerage oer the central hills and the south-Western lowland areas, and part of Northern Province. Day temperatures were mainly about normal, while night temperatures were about or a little above normal. Day humility ranged from 63 to 83 per cent. while night humidity ranged from 80 to 95 per cent. Mean cloud amounts were a little above normal, while the mean air pressures were a little below normal. Wind mileages were above normal in the north and south-east and below normal elsewhere, the direction being generally south-westerly.

JUNE: Overcast skies and occasional rain in the North and East of the Island confirmed the presence of an upper low pressure area over South-west Bay of Bengal at the beginning of the month. On the 3rd, there was intermittent rain or drizzel in the Northern Province and Trincomalee area and satellite data gave the position of a vortex at latitude 11N longitude 83E. By the 5th, a depression was evident, centred at latitude 16N longituyde 89E and the southwesterly pressure gradient across the Island became very steep, with the upper winds westerly to southwesterly and speed 20 to 30 knots up to about 18,000 feet. The south-west monsoon was now fully established with thh I T C Z near latitude 16N. From the 7th onwards, normal south-west monsoon weather prevailed, the heavier showers occuring inland in the south-west and over the hill country. From the 23rd to the 29th, the monsoon weakened and the rain was generally light and confined mainly to the hill country. On the 30th, the westerly air stream became shallow and winds aloft were light. As a result, there was islandwide thunderactivity. Rain was fairly widespread with several stations in the south-west experiencing very heavy rain and recording falls of over 5 inches.

The larger monthly totals of rainfall (totals over 30 inches) were in the Ginigathena area. Rainfall over the adjoining region of the south-west quarter ranged from 20 to 30 inches. Over the southwestern lowland area, rainfall was between 10 to 20 inches decreasing to below 10 inches near the coast. In the North, rainfall was between 2 to 5 inches and over the rest of the Island generally below 2 inches. Several stations in the Northern, North?Central and North-western Provinces evperienced absolute drought conditions. Rainfall was above average over a small area of the south-western lowlands and in the North. Rainfall was below average over the rest of the Island. Day and night temperatures were generally a little above normal. Day humidity ranged from 58 to 85 per cent. while night humidity ranged from 78 to 95 per cent. Mean cloud amounts were about normal, while the mean air pressures were a little below normal. Wind mileage were below normal in the West and East and a little above normal elsewhere, the direction being mainly southwesterly.

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12th September, 1970.

APRIL 1970

Station	Temperature F: Mean Max.	Offset	Mean Min.	Offset	Humidity: Day	Night	Cloud Amount	Rainfall: Amount	Offset	Rain days	Offset
Anuradhapura	92.5	+0.6	75.6	+1.2	72	93	4.6	4.39	—2.97	15	+2
Badulla	85.5	+1.1	67.3	+1.0	75	95	5.2	13.11	+5.37	23	+6
Batticaloa	88.3	+0.4	78.0	+1.2	75	89	5.2	2.15	—0.70	11	+4
Colombo	88.5	Œ0.6	76.1	+0.3	77	91	5.8	17.36	+7.13	22	+4
Diyatalawa	77.4	—0.9	61.7	+1.0	81	97	5.4	13.54	+5.27	24	+6
Galle	86.7	+0.6	76.6	+0.1	70	82	5.4	7.69	—2.25	15	—1
Hambantota	87.7	0	76.9	+0.5	75	86	5.4	5.43	+1.14	10	0
Jaffna	90.3	+0.6	79.9	—0.4	73	85	5.0	2—2	—0.54	11	+4
Kandy	86.6	—1.1	70.6	+0.7	74	92	5.8	7.46	+0.05	19	+7
Kankasanturai	91.2	—0.3	78.3	—0.2	71	89	5.3	2.42	+0.29	8	+ 4
Katunayake	90.6	—	75.5	—	74	93	5.6	24.76	—	20	—
Kurunegala	91.8	+0.7	74.9	+0.3	73	95	5.8	10.13	—0.23	19	+3
Mahailluppalama	92.0	+0.1	75.2	+1.5	67	88	5.2	5.35	—	13	—
Mannar	60.5	+0.3	78.6	+0.5	75	86	5.4	3.79	+0.31	11	+3
Nuwara Eliya	73.0	+1.6	53.7	+3.7	81	94	5.7	7.87	+1.82	19	+8
Puttalam	90.6	+1.1	76.2	+0.1	77	95	5.2	9.75	+4.33	14	+4
Ratmalana	88.7	+0.2	75.5	—0.1	67	84	5.0	16.18	—	19	—
Ratnapura	91.7	+0.4	74.1	+0.4	77	95	6.3	13.60	+0.19	24	+3
Trincomalee	90.7	+1.1	78.5	+0.7	71	86	5.0	3.37	+0.35	8	+1
Vavuniya	92.5	—	75.1	—	62	83	5.6	4.29	—	14	—

MAY 1970

Station	Temperature F1				Humidity		Cloud Amount	Rainfall			
	Mean Max.	Offset	Mean Min.	Offset	Day	Night		Amount Amount	Offset	Rain days	Offset
Anuradhapura	89.7	—1.2	76.5	+0.2	75	91	5.7	4.51	+0.59	8	0
Badulla	86.8	+1.2	67.2	+0.7	71	95	5.2	2.05	—2.45	13	+2
Batticaloa	91.5	+1.11	78.7	+0.8	71	84	5.9	1.32	+0.09	10	+5
Colombo	87.6	+0.6	77.7	+0.1	89	89	6.6	23.72	+9.84	24	+1
Diyatalawa	79.3	+0.6	63.2	+0.8	75	89	5.4	5.65	+0.02	14	0
Galle	85.3	+0.3	78.3	+0.2	76	80	5.8	11.85	—0.05	25	+ 4
Hambantota	86.5	—0.5	78.6	+0.9	80	84	5.8	1.68	—3.08	10	—2
Jaffna	87.9	—0.4	81.4	—0.3	79	83	6.4	5.24	+2.77	5	+1
Kandy	85.0	—0.7	70.5	—0.1	73	92	6.4	3.26	—4.22	18	+7
Kankesanturai	90.5	—1.1	81.0	0	74	82	6.0	4.53	+2.67	7	+3
Katunayaka	88.8	—	76.5	—	80	91	6.8	15.04	—	21	—
Kurunegala	88.9	—0.2	76.2	+0.1	77	91	6.4	10.26	+2.52	15	—1
Mahailluppalama	89.7	—0.4	76.9	+1.1	72	86	6.2	4.52	—	9	—
Mannar	98.3	—0.1	81.0	+0.2	77	82	6.8	1.50	—0.44	7	+3
Nuwara Eliya	70.4	0	56.2	+2.5	83	91	6.4	3.86	—5.46	18	+1
Puttalam	89.3	+0.7	78.8	0	82	93	6.1	3.72	—0.17	12	+2
Ratmalana	87.2	—0.3	76.9	—0.8	82	93	6.6	18.54	—	24	—
Ratnapura	89.2	+0.1	75.3	+0.4	80	95	6.7	10.41	—9.05	24	0
Trincomalee	93.7	+1.2	79.4	+0.5	65	80	5.8	2.62	—0.05	6	0
Vavuniya	90.9	—	76.4	—	63.	82	6.2	2.76	—1.61	10	+3

JUNE 1970

Station	Temperature F. Mean Max.	Offset	Mean Min.	Offset	Humidity Day	Night	Cloud Amount	Rainfall Amount	Offset	Rain days	Offset
Anuradhapura	90.6	+0.6	77.0	+0.6	68	91	5.4	0.23	—0.30	3	—1
Badulla	88.0	+2.4	66.0	+0.5	63	92	4.6	0.14	—0.081	3	—3
Batticaloa	93.3	+0.9	79.0	+1.2	64	78	5.4	0.03	—0.70	1	—2
Colombo	87.4	+2.1	79.3	+1.9	77	85	6.1	5.09	—3.24	19	—3
Diyatalawa	79.4	+1.9	63.1	—0.3	65	84	4.8	1.12	—0.70	4	—4
Galle	85.0	+1.5	78.6	+1.4	76	78	5.0	4.35	—4.32	22	0
Hambantota	88.5	+2.1	79.0	+2.0	73	82	5.8	0.04	—2.13	3	—9
Jaffna	87.0	+0.2	80.8	—0.2	78	82	5.5	1.30	+0.66	4	Œ3
Kandy	83.0	+1.0	71.4	+0.8	74	88	6.5	4.21	—3.06	22	+4
Kankasanturai	90.1	—0.9	80.0	—0.9	71	82	5.7	1.28	+0.72	3	+2
Katunayake	88.9	—	18.4	—	76	86	6.2	6.56	—	16	—
Kurunegala	87.9	+1.4	76.9	+1.2	76	88	6.5	2.14	—4.29	15	—6
Mahailluppallama	90.2	+0.8	77.4	+1.4	65	84	5.6	0.04	—	2	—
Mannar	88.0	0	80.5	—0.2	76	85	6.2	0.02	—0.17	1	0
Nuwara Eliya	66.4	+0.8	56.6	+0.7	85	91	6.6	3.69	—6.79	23	—1
Puttalam	88.8	+2.1	80.1	+0.8	77	87	5.7	0.02	—0.89	2	—4
Ratmalana	87.8	+2.1	78.6	+1.0	78	86	6.1	4.42	—	19	—
Ratnapura	88.1	+1.3	74.9	+0.1	81	95	5.8	14.74	—3.47	25	—1
Trincomalee	93.7	+1.1	79.5	+0.3	61	78	5.7	1.16	+0.43	2	0
Vavuniya	91.8	—	76.4	—	58	79	1.9	0.30	—0.17	3	Œ2