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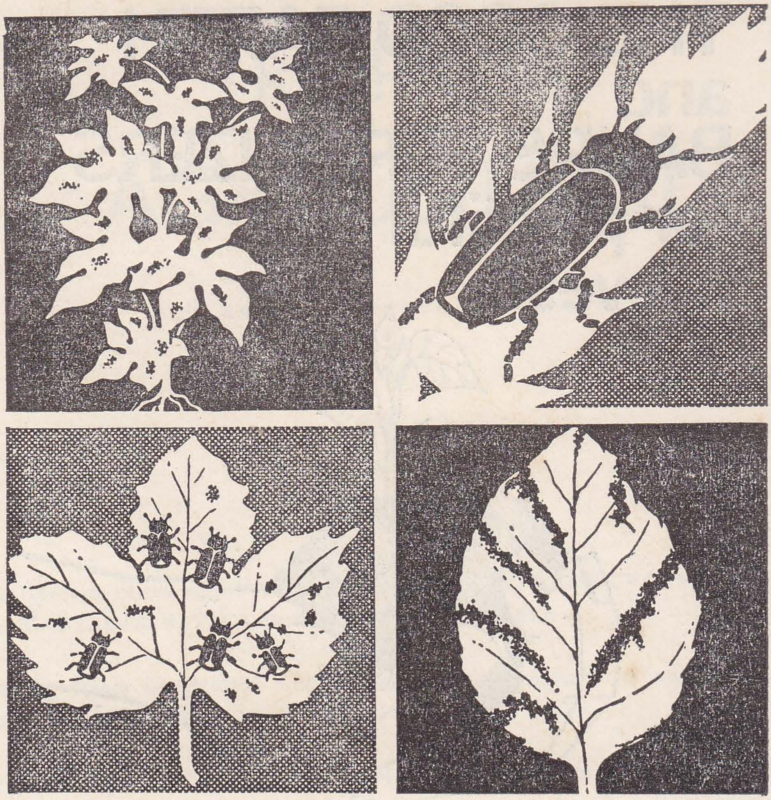

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CONTENTS

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Virus diseases of rice and their control

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[*Received: November, 1969*]

INTRODUCTION

Virus diseases constitute a serious threat to increased rice production in South-East Asian countries. In Ceylon, viruslike symptoms were first reported from Bibile in 1965 (1). Since then, virus diseases have been increasingly recognized in most rice-growing districts and they could develop into epidemic proportions, particularly under conditions of high fertilization, cultivation of susceptible varieties, multiple cropping and haphazard cultural practice.

Three virus diseases, namely Yellow Dwarf, Orange Leaf and Grassy Stunt have been characterized in Ceylon on the basis of their symptoms, vector transmission and virus-vector relationships. This paper reviews experimental work on virus characterization and also discusses complex problems associated with their control in Ceylon.

YELLOW DWARF

Although Yellow Dwarf disease of rice was first reported in Japan in 1919, its presence in tropical Asia has been recognized only during the last decade. In Ceylon, the disease was observed in 1966, and since then, has been found to occur in most rice-growing districts. At the present moment, its distribution in the field is highly sporadic but estimates of infection on ratoon growth, for instance at Peradeniya, have shown up to 20 per cent of infected hills. The crop loss from Yellow Dwarf at this stage could be considered to be insignificant but the disease may assume epidemic importance with extensive cultivation of susceptible and high productive varieties. In Japan, for example, 50,000 acres are known to be severely affected with this disease resulting in an estimated yield loss of about 10,000 tons (2).

The disease is known to be transmitted by three species of green leafhopper, namely *Nephotettix cincticeps* Uhler, *N. impicticeps* Ishihara and *N. apicalis* Motsch (2). Among them, the predominent vectors in tropical Asia are thought to be *N. impicticeps and N. apicalis*. In Japan, the disease is reported to be transmitted principally by *N. cincticeps* (2).

Fig. 1. Natural Infection of Rice with Yellow Dwarf Disease.

Fig. 2. Secondary growth from Rice Stubble infected with Yellow Dwarf Disease.

Symptoms. As illustrated in Figure 1, Yellow Dwarf disease of rice is characterized by general chlorosis of the plant, severe stunting and profuse tillering. Chlorotic symptoms appear initially on new emerging leaves, and chlorosis spreads thereafter to succeeding leaves as well as to tillers and the main stem. When young plants are infected chlorosis becomes pronounced followed by leaves turning whitish brown from tip downward. The leaftips lose turgidity and finally acquire a dirty brown colour. Panicles, if produced, show retarded emergence and the grain is often spotted, defective and remain only partly filled.

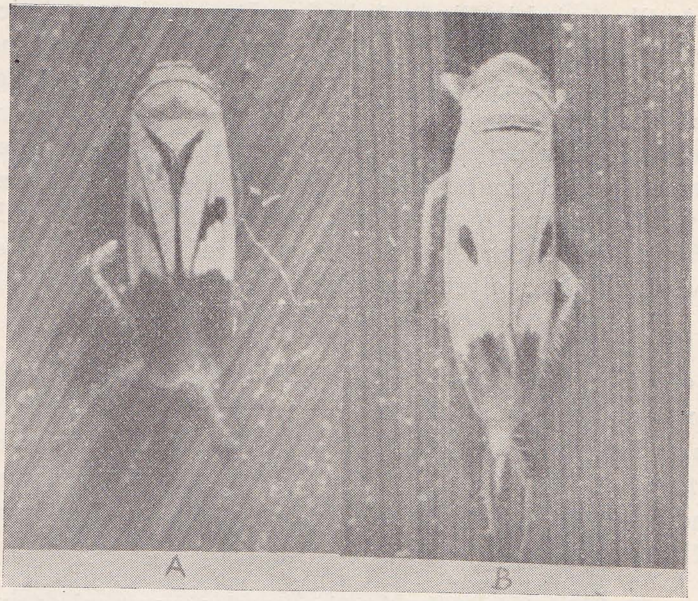
Symptoms of Yellow Dwarf are also frequently seen on secondary growth from rice stubbles, and the affected hills can be readily distinguished from a distance. Given in Figure 2 are infected secondary growth from rice stubbles with characteristic symptoms of pronounced yellowing, and profuse tillering. Infected ratoons have smaller leaves than those of healthy hills.

Transmission. Four leaf and planthopper species commonly found to colonize rice in Ceylon were experimentally tested for their ability to transmit Yellow Dwarf. They were *N. apicalis, N. impicticeps, Inazuima dorsalis* Motsch *and Nilaparavata lugens Staol.* Among them, only green leafhoppers *N. apicalis* and *N. impicticeps* (Figure 3) were determined to be active transmitters.

Shinkai, working in Japan, experimentally demonstrated the transmitting ability of *N. apicalis* to be lower than that of either *N. impicticeps* or *N. cincticeps.* In the present investigation, however, no differential transmitting ability of either *N. apicalis* or *N. impicticeps* was observed. Both species were equally efficient and gave 60 percent positive transmission of the disease.

Virus-vector relationships. In experiments to determine the optimum number of vectors required to produce highest transmission, no substantial difference in the transmitting ability between a single vector, or groups of 2 or 3 vectors was observed.

The incubation period of the virus when determined by the appearance first visual symptoms in the rice variety Taichung (Native) I varied from 25-90 days. On the other hand, its incubation period in the vector (*N. impicticeps* was found to vary from 20-55 days. Illustrated in Figure 4 is the effect of the period of incubation of the virus on the transmitting ability of the vector. The transmissing ability of the



(A) (B)

Fig. 3. Vectors of Yellow Dwarf Disease.
A—Nephotettix apicalis.
B—Nephotettix impicticeps.

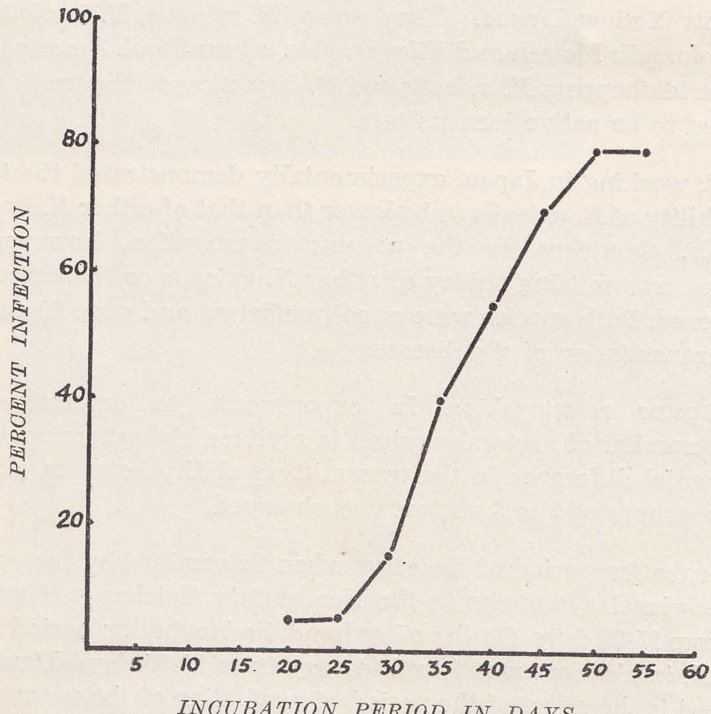


Fig. 4. Effect of incubation period of Yellow Dwarf Virus in Nephotettix impicticeps *on transmission.*

vector increased with the increase in incubation period from 20-55 days. Disease transmission was highest when insects were given a 45-50 day incubation period of the virus.

The basic relationship of virus-vector has been established to be persistent. Early instar larvae of N. *impicticeps* were fed on a virus source and given an incubation period of 35 days prior to serial transfer to test plants. Shown graphically in Figure 5 are results of a typical experiment on serial transmission of the disease. It will be noted that a single viruliferous leafhopper was able to transmit the disease to more than 10 plants in succession, and that its transmitting ability increased up to the seventh successive transfer. The observed increase in transmitting ability could, therefore, be attributed to the extended incubation of the virus, thus confirming that an optimum incubation period of 40-50 days was required to give maximum vector efficiency.

The results of experiments described on virus-vector relationships and on transmission of Yellow Dwarf thus revealed that (1) a single vector was sufficient to obtain maximum infection, (2) an incubation period of 45-50 days of the virus in its vector was required for maximum transmission, (3) a single vector was able to infect more than 10 plants serially without having to feed on a fresh virus source, or without any substantial loss in its transmitting ability, and finally (4) both *N. impicticeps* and *N. apicalis* possess an equal transmitting ability of Yellow Dwarf disease. It follows, therefore, that the above improvements for effective transmission of Yellow Dwarf could be profitably applied in a mass screening of rice varieties for disease resistance.

Tests on varietal resistance. A series of tests on resistance or susceptibility of rice varieties to Yellow Dwarf were undertaken employing improved methods of disease transmission. Reported in Table 1 are the results of the first varietal evaluation involving 8 indigenous and introduced rice varieties.

Test seedlings placed in glass tubes were inoculated at 2-3 leaf stage, 25 seedlings per variety. Sedlings thus inoculated were grown in 6″ clay pots and disease estimates taken on the basis of visual expression of symptoms of yellowing, profuse tillering and stunting of plants.

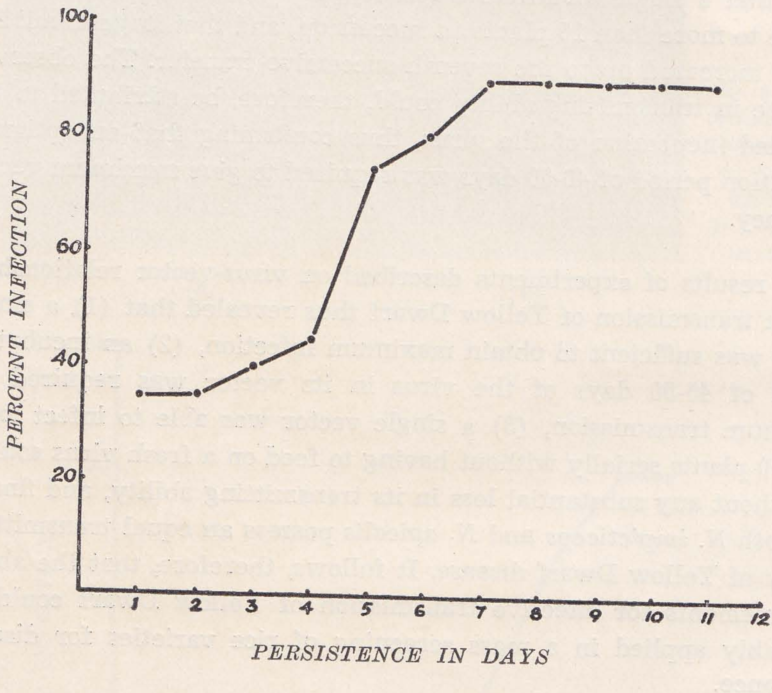


Fig. 5. Persistence of Yellow Dwarf virus Nephopetettix impicticeps

TABLE 1

Relative Resistance of Rice Varieties to Yellow Dwarf

Variety	*Percent Infection*
H 4	20
H 102	40
Chianung 242	60
Taichung (Native) I	75
IR 8	80
Remadja	90
H 6	100
Heenati 309	100

No differential reactions were observed among the rice varieties, nevertheless the degree of infection varied considerably. Based on the latter, H4 emerged as most resistant, H 102 and Chianung 242 showed moderate infection while IR 8, Remadja, H6 and Heenati 309 exhibited susceptibility.

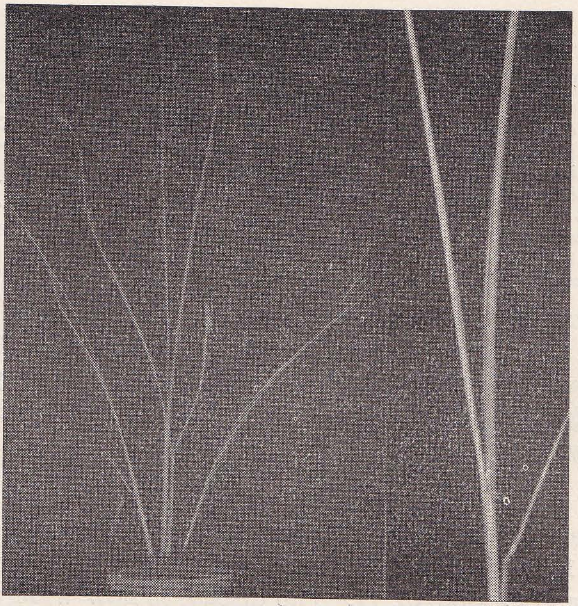
ORANGE LEAF

Orange Leaf virus disease of rice was first reported from northern Thailand in 1960 (4). It has since been found to occur in the Philippines and Ceylon (5, 1). The disease is now widely distributed in the country but its occurrence is highly sporadic and shows a scatter distribution in the field. In fields at Peradeniya, secondary growth from rice stubbles showed up to 5.6 per cent of infected hills (1).

Symptoms. The characteristic symptoms of the disease is the appearance of conspicuous bright orange colour in the leaves of the rice plant. The orange colour appears as streaks running from leaftip downward, and in certain cases, these streaks are confined to only one side of the leafblade. Leaf margins roll inward commencing at the leaftip and progresses downward (Figure 6). Infected plants show reduced tillering, and in a great majority of infections, the plants are finally killed. Panicles show retarded exsertion, and the grain becomes discoloured and partly filled. When 2-3 leaf seedlings are infected, they are rapidly killed.

Transmission. Experimental inoculation studies revealed that the disease is transmitted by the zig-zag leafhopper *Inazuma dorsalis* Motsch (Figure 7). No positive transmission was obtained with other species of rice leaf and planthoppers *viz. Nephotettix apicalis, N. impicticeps* and *Nilaparvata lugens.* This partly confirms the findings of Rivera *et al* on insect transmission of the Orange Leaf disease (5).

Virus-vector relationships. Vector efficiency in transmitting the Orange Leaf disease was improved by an increase in the number of insects per test plant. Experiments revealed that an insect group of 3 was superior to either a group of 2, or a single insect. A further increase in the number of insects from 3 to 8 per group per test



(A) (B)

Fig. 6. Orange Leaf Disease.
A—Severely infected plant.
B—Inward Rolling of Leaves.

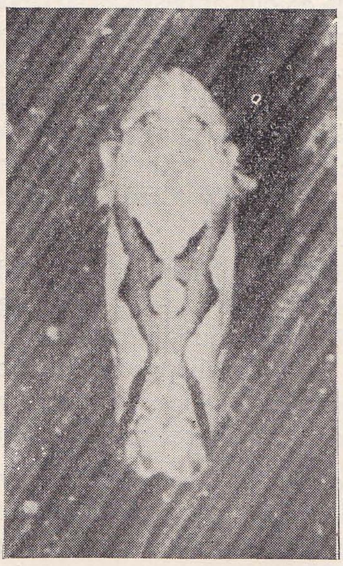


Fig. 7. Vector of Orange Leaf Disease Inazuma dorsalis.

seedling did not result in increased transmission of the disease. The relationship of virus-vector was determined as persistent. In serial transmission studies, a single viruliferous vector was found to be capable of infecting over 4 plants in succession without having to feed on a fresh virus source.

Tests on varietal resistance. Thirty two indigenous, hybrid and introduced rice varieties were experimentaly inoculated to determine their resistance or susceptibility to Orange Leaf disease. In this investigation, viruliferous vectors were transferred to 2-3 leaf seedlings contained in test tubes and given an inoculation feeding period of 24 hours. Seedlings, thus inoculated, were planted in clay pots and disease appearance and severity data taken at regular intervals. Illustrated in Table 2 is the percent infection and symptoms exhibited by each test variety.

TABLE 2

Varietal Reaction of Rice to Orange Leaf Disease

Variety	*Per cent. infection*	*Symptoms observed*
Pachchaiperumal	100	Orange colour of leaves, pronounced leaf rolling and death of seedlings
Murunga 307	100	do.
H-106	100	do.
H-105	90	
Murungakayan 303	80	do.
Murungakayan 304	80	do.
Murungakayan 104	80	do.
Heratwi	80	do.
Vellai Illankalayan	80	do.
Hal Suduwi	80	do.
Murunga 308	80	do.
Dahanala	80	do.
Pokkali	80	do.
Vellaiperunel	80	do.
H 4	80	do.
H 501	80	do.
Pinulot	80	do.
Mas 24	80	do.
IR 8	80	Orange colour of leaves, leaf rolling not pronounced
IR 5	70	do.
Murungakayan 302	70	Orange colour of leaves, pronounced leaf rolling and death of seedlings
Dewaradderi	70	do.
Tadukan	70	Brown colour of leaves, leaf rolling not pronounced
Ratuwi	60	Orange colour of leaves, pronounced leaf rolling and death of seedlings
Dickwi	60	do.
Ptb 16	60	do.
H 7	50	do.
H 102	50	do.
Bengawan	50	do.
Elwee	50	Orange colour of leaves, no rolling of leaves
Podiwi-a8	40	Orange colour of leaves, pronounced leaf rolling and death of seedlings
Kalu Dahanala	20	Yellowing of leaves, no leaf rolling or death of seedlings

All rice varieties tested developed systemic infection and no recognizable differences existed in the severity of disease reaction in a population of plants in any single variety. However, varieties investigated showed conspicuous differences both in the severity of infection as well as their reaction to disease. Thus, differentiation of varieties as susceptible, resistant or tolerant was possible.

The cultivated varieties H4, H7, H105, H501, Pachchaiperumal, Murungakayan 302, Pokkali and Podiwi-a8 were susceptible and showed a severe reaction to disease which included the development of intense orange colour followed by inward rolling of leaves, and finally death of seedlings. Varieties such as IR 8, IR 5 and Elwee showed a high degree of infection but did not react violently with leaf rolling symptoms. Kalu Dahanala reacted with mild symptoms of leaf yellowing but the disease neither caused rolling of leaves nor death of seedlings. Hence, it could be categorized as a tolerant variety, and has potential importance as a genetic source in breeding for resistance or tolerance to Orange Leaf.

GRASSY STUNT

Grassy Stunt disease was first reported in the Philippines in 1963 (6). In Ceylon, it is highly sporadic in occurrence and has been commonly found to affect the variety IR 8.

Symptoms. The disease at a glance resembles Yellow Dwarf. The virus causes severe stunting, profuse tillering, and the leaves are generally tufted and erect (Figure 8). On older leaves, rusty brown specks appear. Panicle exsertion is often retarded and the grain becomes spotted and generally unfilled or half-filled.

Transmission. The disease was experimentally transmitted with the brown planthopper *Nilaparvata lugens* Stal (Figure 9). The incubation period in the rice plant was determined as 10-14 weeks.

CONTROL OF RICE VIRUS DISEASES

Until broad-based resistant or tolerant varieties are developed by rice breeding, control of virus diseases must be accomplished by integration of field sanitation, management practice and elimination of vectors.

Virus diseases persist between *maha* and *yala* cropping seasons in secondary growth from rice stubbles which thus serve as sources of initial infection. In ill-drained fields, particularly in the wet zone, the

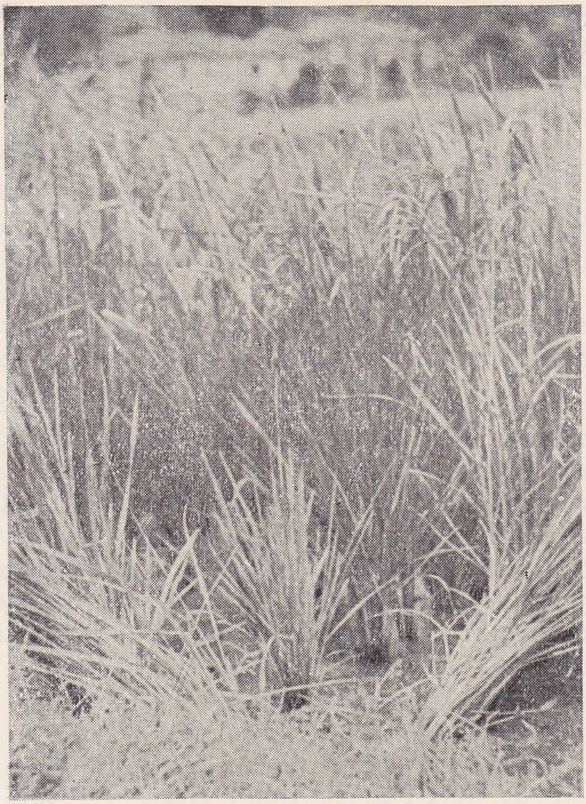


Fig. 8. Natural Infection of Rice with Grassy Stunt Disease.

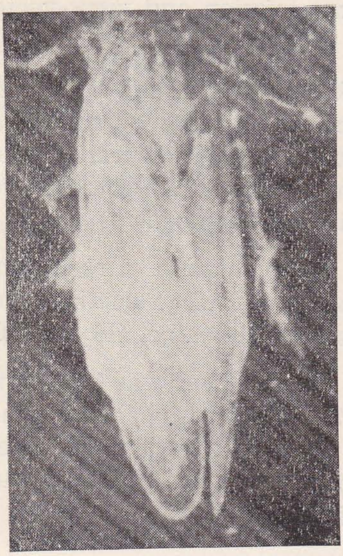


Fig. 9. Vector of Grassy Stunt Disease Nilaparvata lugens.

prevalance of secondary growth from uncontrolled rice stubbles poses special problems in virus control. In such situations, good field hygiene and post-harvest eradication of virus reservoirs are of the utmost importance.

Management practice aimed at virus control must necessarily include attention in many details such as avoidance of staggered planting, elimination of haphazard and mixed cultivation of varieties of different age classes, and finally, eradication of all potential sources of infection. Best results from above practices could be achieved by their integrated and combined application on a contiguous *yaya* or area basis rather than on scattered farmer's fields.

In localities where virus diseases are endemic, good management practice and field hygiene should necessarily be combined with vector control. Leafhopper and planthopper vectors of rice virus diseases could be eliminated by insecticide application. This method is particularly useful for vector control in nurseries. Spraying of nurseries will result in elimination of early infections that are generally responsible for heavy crop losses. Indirect control of rice virus diseases could also be accomplished by breeding and development of rice varieties with resistance to vector infestation.

SUMMARY

The identity of three virus diseases of rice *viz* Yellow Dwarf, Orange Leaf and Grassy Stunt has been established on the basis of symptoms, transmission and virus-vector relationships.

Yellow Dwarf was transmitted by green leafhoppers *N. apicalis* and N. *impicticeps,* and both species exhibited equal transmitting ability. Experiments have demonstrated that a single vector was sufficient to obtain maximum transmission, an incubation period of 45-50 days in the vector was necessary for maximum transmission and that the virus is persistent.

An evaluation of resistance or tolerance of indigenous, hybrid and introduced rice varieties revealed that H4 was highly resistant whereas IR 8, Remadja, H6, and Heenati 309 showed extreme susceptibility.

Orange Leaf was transmitted by the zig-zag leafhopper I. *dorsalis.* The transmitting ability of a group of 3 insects was superior to that of a group of 2, or a single insect. A single viruliferous vector was able to infect over 4 plants in succession without having access to a fresh virus source.

Thirty-two rice varieties were evaluated for resistance to Orange Leaf. Widely cultivated varieties such as H4 and Pachchaiperumal were highly susceptible. IR 8, IR 5 and Elwee did not react violently, while Kalu Dahanala was tolerant and exhibited only leaf yellowing symptoms.

Grassy Stunt was transmitted by the brown planthopper *N. lugens*. The incubation period of the virus in the host was found to be 10-14 weeks.

Control of rice virus diseases is discussed with special reference to an integrated approach through field sanitation, management practice and vector elimination.

ACKNOWLEDGMENT

The authors are grateful to Messrs R. P. Goonatillaka and A. Ratnayake for the preparation of illustrations for this publication.

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Thirty-two rice varieties were screened for resistance to Orange Leaf. Widely cultivated varieties such as H4 and [illegible] were highly susceptible. IR 8, IR 5 and [illegible] did not react [illegible], while Kalu Dahanala was [illegible] and exhibited only [illegible] symptoms.

Orange Leaf was not carried by the brown planthopper [illegible]. The incubation period of the virus in the host was found to be [illegible] days.

Control of rice virus diseases is discussed with special reference to an integrated approach through field sanitation, management practices and vector control.

ACKNOWLEDGEMENTS

The authors are grateful to Messrs. R. [illegible] and [illegible] for the preparation of illustrations for this publication.

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Spraying trials on potato blight control with organo-tin and other fungicides

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[Received : November, 1969]

SUMMARY

In screening trials on the control of late blight of potatoes at Sita Eliya in the hill country wet zone of Ceylon, yields with dithiocarbanate fungicides were consistently superior to those with organo-tin and other formulations. For effective control of the disease, it was important to apply the first spray before the onset of infection, and thereafter approximately seven more sprays at 10 day intervals were adequate to ensure a vigorous healthy crop virtually free from late blight. Phytotoxic effects were associated with the organo-tin fungicides, especially Brestan 60, which caused distortion of foliage, stunting, and depression of yields. These effects were most pronounced during an excessively wet season while during a moderately wet season the performance of the organo-tin fungicides applied on a 10 day spraying schedule compared favourably with that of the dithiocarbamates. The most efficient fungicides were Dithane M-45 and Manzate D (mancozeb), Lonacol M, Dithane M-22 and Mangan Curit (maneb) and Antracol (propineb), all of which gave good control of the disease when applied at the rate of 2 lb/100 gal. The most suitable rates for the organo-tin fungicides were 3 oz /100 gal. for Brestan 60 (triphenyltin acetate + maneb) and 12 oz/100 gal for Du-Ter (triphenyltin hydroxide). Substantial economic gains would accrue from the control of blight by fungicidal spraying and it is apparent that without such measures potato cultivation is not an economic venture under our conditions in the present circumstances.

INTRODUCTION

Late blight has long been recognised as one of the most important diseases of potato. It is common in both the wet and the dry zones of the hill country of Ceylon. Crop losses due to premature defoliation and tuber infection could often be considerable. For the successful cultivation of potatoes it is essential to adopt measures against the disease such as the use of resistant varieties, the selection of planting seasons so as to avoid periods favouring disease incidence, and the control of the disease by fungicidal spraying (Peiris & de Zilva, 1954 ; Abeygunawardena & Peiris, 1958 ; Abeygunawardena, 1960 ; Abeygunawardena & Balasuriya, 1961 ; Caesar & Ganesan, 1963). Practical considerations, however, have an important bearing on such measures. For instance, the resistance of varieties has been found to break down with time, e.g., Gineke, Dekama and Cosima, while varieties relatively susceptible to blight may have other desirable characteristics to commend them. In the hill country wet zone of Ceylon with a well distributed rainfall, conditions generally favourable to the disease occur during much of the year. In these circumstances fungicidal spraying for the control of blight is an important aspect of potato cultivation.

In previous work on the control of late blight (Peiris & de Zilva, 1954, ; Abeygunwardena, 1960 ; Caesar & Ganesan, 1963), the fungicides chiefly studied in screening trials were the coper and dithiocarbamate formulations. In recent years, organo-tin fungicides have been developed consequent on the discovery of the high fungicidal efficacy of the organic compounds of tetravalent tin. Ventura & Herve[1] (1962) reported the efficacy of triphenyltin acetate against blight and its effects on different varieties including the stunting of terminal leaves and the reduction of yields. In comparative trials with copper, dithiocarbamate, and organo-tin fungicides, Holmes & Storey (1962) reported that triphenyltin acetate alone had a direct effect on the reduction of tuber blight. In the trials reported here, two commercial organo-tin fungicides, Brestan 60 (triphenyltin acetate + maneb) and Du-Ter (triphenyltin hydroxide) were compared with a number of other fungicides including some of the more recent dithiocarbamates such as Antracol, Dithane M-45 and Manzate D. Various rates of application of the fungicides and the effect of spraying before and after the onset of blight infection were investigated.

EXPERIMENTAL METHODS

The trials were conducted during the three seasons Maha 1963-64, Yala 1964 and Maha 1964-65 at Sita Eliya (6,200 ft.) in the hill country wet zone which is characterised by a cool temperate type of climate. In this zone rainfall is evenly distributed throughout the year with two peak periods during the monsoons (Fig. 1).

The development of late blight epidemics is determined mainly by the prevailing conditions of rainfall, dew, humidity, temperature and wind which influence the production of spores and their dispersal, The total rainfall, the number of rain days, and the average minimum and maximum temperatures for 10 day periods from 31-90 days for each of the trials are shown in Fig. 2.

For all the trials, a randomised block design with four replicates was used, the plot size being 12 ft × 15 ft inclusive of a 1 ft bund and a 1 ft drain. The planting area per plot was 10 ft × 15 ft which accommodated ninety tubers planted in ten rows of nine tubers per row at a spacing of 1½ ft. between rows and 12-13 in. within rows. The susceptible variety Gineke was used in all the trials. The fertilizer dressing applied was as follows :—

Sulphate of ammonia—500 lb/acre

Conc. superphosphate—750 lb/acre

Muriate of potash—133 lb/acre

Cattle manure—5 tons/acre

Sprays were applied with knapsack sprayers during the morning session. Moveable screens were used to prevent spray drift. Afternoons were often wet in this zone and early spraying allowed adequate time for drying of the fungicidal treatment. As only one particular treatment was applied at a time, the order of spraying of the different treatments was changed on each occasion. This procedure also offset to some extent the adverse effects of light showers on the efficacy of different fungicidal sprays on a few occasions.

Treatments were varied in the trials depending on clear indications as the series progressed. Thus, in the trials during Maha 1963-64, several treatments with Brestan 60 were included, many of which were eliminated in later trials. In Yala 1964, a maneb fungicide (Dithane M-22) was used alternating with and in combination with Brestan 60 to determine whether this would reduce the phytotoxic effects of the organo-tin fungicide. From the early trials it was clear that the first fungicidal spray had to be applied before the onset of infection. In the Maha 1964-65 trials, therefore, the main objectives were to compare the efficacy of the fungicides when applied preventively, and finally to determine whether a 10 day spraying interval would ensure adequate protection in a spary programme commencing before the onset of infection.

Late blight infection was assessed according to the B. M. S. key (Anon. 1947) and phytotoxic effects on a rating scale of 0-5 where 0 = no phytotoxic symptoms and 5=very severe phytotoxic symptoms.

The fungicide screened in six trials, two each during the season Maha 1963-64, Yala 1964 and Maha 1964-65 are listed in Table 1.

RESULTS

Data on the following six trials are presented in Tables 2-7.

(1) Maha 1963-64, trial I, planted on 18 October, 1963 (Table 2).

(2) Maha 1963-64, trial II, planted on 8 November, 1963 (Table 3).

(3) Yala 1964, trial I, planted on 20 March, 1964 (Table 4).

(4) Yala 1964, trial II, planted on 20 March, 1964 (Table 5).

(5) Maha 1964-65, trial I, planted on 18 September, 1964 (Table 6).

(6) Maha 1964-65, trial II, planted on 5 November, 1964 (Table 7).

The three seasons during which the trials were conducted were representative of the weather conditions that could be encountered in the hill country wet zone. Maha 1963-64 was a very wet season and conditions very favourable to blight were encountered. Yala 1964 was relatively dry and blight was not severe. Maha 1964-65 was again wet and represented the conditions of an average season.

The outstanding fungicides were the dithiocarbamate formulations, Dithane M-45 and Manzate D (mancozeb), Lonacol M, Dithane M-22 and Mangan Curit (maneb), and Antracol (propineb). They achieved excellent control of the disease during all types of seasons, produced vigorous crops free from phytotoxic effects, and gave the highest yields. For the four trials during the Maha seasons, the yields of the best treatments in comparison with the unsprayed controls (taken as 100%) were 254% (Lonacol M, Maha 1963-64, trial I), 284% (Dithane M-45, Maha 1963-64, trial II), 367% (Lonacol M, Maha 1964-65, trial I) and 268% (Manzate D, Maha 1964-65, trial II).

The organo-tin fungicides, Brestan 60 and Du-Ter were very effective in controlling the fungus. However, they also caused adverse effects on the plants which, in general, were somewhat stunted and lacked the health and vigor of plants treated with dithiocarbamate fungicides (Fig. 4, bottom left). Phytotoxic symptoms on the foliage were more pronounced with Brestan 60 (Fig. 4, top left) than with Du-Ter (Fig. 4, top right), and with the former the most severe sypmtoms were observed during the very wet Maha season of 1963-64. The effect of organo-tin fungicides on tuber blight could not be determined because the incidence of tuber blight in these trials was negligible. Yields from the organo-tin treatments were lower than those from the dithiocarbamates and the differences between the best dithiocarbmate and organo-tin treatments were, with one exception, significant at the 5% level in all the Maha trials.

In Maha 1963-64, fungicidal spraying commenced after and before the onset of late blight infection in trials I and II respectively. While the best treatment in the former yielded only 3.00 tons/acre, in the latter the highest yield was 5.74 tons/acre. The two yields are not strictly comparable. Nevertheless, these trials indicated the importance of applying fungicidal sprays before the onset of infection and the advantage of this practice on the growth and vigour of the crop was apparent in subsequent trials. Further, with preventive spraying, a 10 day interval between successive sprays was adequate to ensure a vigorous crop and a good yield. In the absence of fungicidal protection late blight invariably caused severe damage (Fig. 4, bottom right).

ECONOMICS OF SPRAYING

Yields are substantially increased by the efficient control of blight and an attempt may be made to determine the economics of fungicidal spraying. In Tables 8 and 9 the cost of fungicides for blight control are worked out for two rates of spray fluid, 100 and 150 gal./acre, and for a total of four, five, six, seven or eight spray applications during a season. The cost of a lb of fungicide has been arbitrarily taken at Rs 4, 5 or 6. The minimum and maximum quantities of fungicides estimated as required for a season to spray an acre are 8 and 24 lb., respectively. If the cost of a lb of fungicide is assumed, for convenience, to be Rs. 5, then the expenditure on fungicides will range from Rs 40 (8 lb) to Rs 160 (32 lb). Yields may be increased by 2-5 tons/acre by the efficient control of blight. Assuming the price of potatoes to be Rs 896/ton, the profits accrued are given in Table 10. In the case of cultivators who carry out the spray operations themselves, this will virtually represent the nett profit. In farms, allowance will have to be made for operational costs. Appropriate changes can also be made in the tables where the cost of fungicides, potatoes, etc., differ from the figures considered.

DISCUSSION AND CONCLUSIONS

Control of late blight of potatoes must be considered in the context of two other important aspects which influence to a great extent the cultivation and extension of the crop in Ceylon. The first is the bacterial wilt disease caused by *Pseudomonas solanacearum* for which there is as yet no practical means of control and which therefore necessitates the longest possible interval between successive crops on the same soil. The second is the limited acreage available in the potato farms for local seed production. With these two limitations it is essential to eliminate losses from late blight and to maximise the yields from the land cultivated each season.

The trials described indicate clearly the importance of applying the first fungicidal spray before the onset of infection—generally between 25-35 days after planting. Thereafter, an interval of 10 days between successive sprays is adequate to keep the crop practically free from the disease. Under the conditions in Ceylon, the growing season has a duration of about 90-110 days and 6-8 sprays will therefore be required during a season to ensure a vigorous blight-free crop. On the other hand, once the disease has established itself on the crop, fungicidal sprays are much less effective. Thus the timing of the first spray before the onset of infection is of critical importance.

Of the fungicides tested, the following six dithiocarbamates are considered the most suitable—Dithane M-45 and Manzate D (mancozeb), Lonacol M, Dithane M-22 and Mangan Curit (maneb) and Antracol (propineb).

The organo-tin fungicides gave lower yields than the dithiocarbamates. However, they were highly fungitoxic at relatively low rates of application, 3 oz/100 gal with Brestan 60 and 12 oz/100 gal with Du-Ter. The expression of phytotoxic symptoms was most severe during the Maha 1963-64 season but comparatively mild during Maha 1964-65. The rainfall and temperature conditions at the stage when plants are most susceptible to phytotoxic injury during these two seasons are summarised in Table II. This suggests that excessively wet conditions aggravate phytotoxic effects. During Maha 1964-65, the performance of the organo-tin fungicides compared favourably with some of the dithiocarbamates, especially in Maha 1964-65 trial II with a 10 day spraying interval. The use of Brestan 60 at 3 oz/100 gal may perhaps be more economical than the use of dithiocarbamates during a moderately wet season. However, the decision on the choice of a fungicide in such circumstances will depend on whether reduced yields (in comparison with the dithiocarbamates) will be acceptable. Because of the importance of maximising yields from a limited cultivable acreage each season, control of blight by less economical measures which ensure the highest yields may be preferred. However, the possibility of combining dithiocarbamates with the organo-tin fungicides in a spray programme deserves consideration. The dithiocarbamates can be used for the early sprays when the plants are most sensitive to phytotoxic damage from organo-tin fungicides. In the later stages of the crop the latter can be used. Such a scheme will probably avoid the adverse effects of the organo-tin fungicides while utilizing their beneficial action on the control of tuber blight.

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TABLE 1—Fungicides screened in the trials

Fungicide	*Active ingredient*	*A.I.* (%)
Brestan 60	Triphenyltin acetate + manganese ethylenebis-dithiocarbamate (maneb)	60+20
Du-Ter	Triphenyltin hydroxide	20
Dithane M-45	Complex of zinc and maneb (mancozeb)	80
Manzate D	Mancozeb	80
Dithane M-22	Maneb	80
Lonacol M	Maneb	80
Mangan Curit	Maneb	80
Dithane Z-78	Zinc ethylenebisdithiocarbamate (zineb)	78
Antracol	Zinc propylenebisdithiocarbamate (propineb)	70
Cupravit (Ob 21)	Copper oxychloride	50
Fungicide 328	3,3[1]—ethylenebis (tetrahydro-4,6- dimethyl-2H-1, 3, 5-thiadiazine-2-thione)	75

TABLE 2—Effect of fungicides on the control of late blight in Maha 1963/64, trial I

Planted on : 18.10.63.

Spraying commenced with the onset of infection and sprays were applied at 7 day intervals

Sprayed on : 20.11, 27.11, 4.12, 11.12, 18.12, 24.12 and 1.1.64.

Fungicide	*Rate/ 100 gal*	*Mean % blight at 9 weeks*	*Mean phytotoxic injury at 9 weeks*	*Mean yield, tons/acre*
Brestan 60	6 oz	10·0	3·0	1·79
Dithane Z-78 alternating with Brestan 60*	2 lb / 8 oz	13·8	0·5	2·37
Du-Ter	1 lb	17·5	1·1	2·39
Du-Ter	1¼ lb	11·3	0·8	2·96
Lonacol M	2½ lb	5·5	0·0	3·00
Dithane Z-78	2 lb	16·3	0·0	2·47
Antracol	2 lb	10·3	0·0	2·73
Antracol	2½ lb	6·3	0·0	2·82
Control	—	90·0	—	1·18
L. S. D. (P=0·05)				0·55

* Four sprays of Dithane Z-78 and three of Brestan 60 ; first spray with Dithane Z-78.

TABLE 3—Effect of fungicides on the control of late blight in maha, 1963/64, trial II

Planted on 9 8.11.63.

Spraying commenced before the onset of infection and sprays were applied at 7 and 14 day intervals.

Sprayed on : 7 day interval*—29.11, 6.12, 13.12, 20.12, 27.12, 3.1.64, 10.1, 17.1 and 24.1.

14 day interval —29.11, 13.12, 27.12 and 10.1.64.

Fungicide	*Rate/ 100 gal*	*Spraying interval in days*	*Mean % blight at 9 weeks*	*Mean phytotoxic injury at 9 weeks*	*Mean yield, tons/acre*
Brestan 60	4¼ oz	7	0·1	3·1	3·24
Brestan 60	4¼ oz	14	23·8	0·8	3·14
Breatan 60+S	4¼ oz	7	0·1	3·5	3·38
Brestan 60+S	4¼ oz	14	16·3	0·8	3·08
Brestan 60	7¼ oz	7	0·1	4·1	2·57
Brestan 60	7¼ oz	14	17·5	1·0	3·22
Brestan 60+S	7¼ oz	7	0·1	3·8	2·99
Brestan 60+S	7¼ oz	14	21·3	1·1	2·48
Brestan 60	8½ oz	7	0·1	4·1	2·82
Brestan 60	8½ oz	14	12·5	1·4	2·83
Brestan 60+S	8½ oz	7	0·1	4·3	2·68
Brestan 60+S	8½ oz	14	7·5	1·3	3·72
Du-Ter	1 lb	7	0·1	0·5	3·94
Du-Ter	1¼ lb	7	0·8	1·5	3·38
Dithane M-45	2 lb	7	0·0	0·0	5·74
Dithane Z-78	2 lb	7	0·1	0·0	4·86
Antracol	2 lb	7	0·0	0·0	5·04
Antracol	2½ lb	7	0·0	0·0	5·35
Control	—	—	95·0	—	2·02
L.S.D. (P=0·05)					0·90

* Treatments with Brestan 60 and Du-Ter were not sprayed on 24·1.

S—Sticker Agrotin 300 added to spray fluid at the rate of 16 fl. oz./100 gal.

TABLE 4—Effect of fungicides on the control of late blight in Yala, 1964, trial I

Planted on : 20.3.64.

Spraying commenced before the onset of infection and sprays were applied at 7 and 10 day intervals.

Sprayed on : 7 day interval—15.4, 22.4, 29.4, 6.5, 13.5, 20.5, 27.5 and 3.6.
10 day interval—15.4, 25.4, 5.5, 15.5, 23.5 and 2.6.

Fungicide	*Rate/ 100 gal.*	*Spraying interval in days*	*Mean % blight at 9 weeks*	*Mean yield, tons/acre*
Dithane M-45	2 lb	7	0·0	6·85
Dithane M-45	2 lb	10	0·0	7·36
Lonacol M	2 lb	7	0·0	8·24
Lonacol M	2 lb	10	0·0	6·22
Mangan Curit	2 lb	7	0·0	6·55
Mangan Curit	2 lb	10	0·0	6·55
Dithane Z-78	2 lb	7	0·0	7·79
Dithane Z-78	2 lb	10	0·0	6·73
Antracol	2 lb	7	0·0	6·65
Antracol	2 lb	10	0·0	7·54
Fungicide 328	1¼ lb	7	0·0	7·44
Fungicide 328	1¼ lb	10	0·0	7·01
Control	—	—	50·0	5·53

Differences were not significant at P=0·05.

TABLE 5—Effect of fungicides on the control of late blight in Yala, 1964, trial II

Planted on : 20.3.64.

Spraying commenced before the onset of infection and sprays were applied at 7 and 14 days intervals.

Sprayed on : 7 day interval—15.4, 22.4, 29.4, 6.5, 13.5, 20.5, 27.5 and 3.6.
14 day interval—15.4, 29.4, 13.5 and 27.5.

Fungicide	*Rate 100 gal.*	*Spraying interval in days*	*Mean % blight at 9 weeks*	*Mean phytotoxic injury at 9 weeks*	*Mean yield, tons/acre*
Brestan 60+S	8 oz	14	0·0	1·4	6·49
Brestan 60 alternating with Dithane M-22*	8 oz 2 lb	7	0·0	0·4	7·27
Brestan 60+ Dithane M-22	8 oz 1½ lb	7	0·0	0·5	6·73
Du-Ter	1 lb	7	0·0	0·0	6·50
Du-Ter+ Dithane M-22	1 lb 1 lb	7	0·0	0·0	7·24
Dithane M-22	2 lb	7	0·0	0·0	7·58
Control	—	—	58·8	—	6·73

Differences were not significant at P=0·05.

* Four sprays of Brestan 60 and four of Dithane M-22 ; first spray with Brestan 60.

TABLE 6—Effect of fungicides on the control of late blight in maha, 1964/65, trial I

Planted on : 18.9.64.

Spraying commenced with the onset of infection and sprays were applied at 7 day intervals.

Sprayed on : 28.10, 4.11, 11.11, 18.11, 25.11, 2.12, 9.12, 16.12, 23.12, 30.12 and 6.1.65.

Fungicide	*Rate/ 100-gal.*	*Mean % blight at 10 weeks*	*Mean phyto-toxic injury at 10 weeks*	*Mean yield, tons/acre*
Brestan 60	3 oz	1·8	1·4	7·04
Du-Ter	12 oz	1·6	0·8	7·03
Du-Ter+ Dithane M-22	12 oz 4 oz	0·1	0·6	7·99
Dithane M-45	2 lb	0·1	0·0	9.92
Manzate D	2 lb	0·3	0·0	9·06
Dithane M-22	2 lb	0·0	0·0	9·57
Lonacol M	2 lb	0·1	0·0	10.49
Mangan Curit	2 lb	0·4	0·0	9.20
Dithane Z-78	2 lb	0·8	0·0	6.57
Antracol	2 lb	0·3	0·0	8.22
Cupravit (Ob 21)	6 lb	0·6	3·1	7.03
Fungicide 328	1 lb	2·8	0·0	5.83
Control	—	31·3	—	2·86
L. S. D. (P=0·05)	—	—	—	1·96

TABLE 7—Effect of fungicides on the control of late blight in Maha, 1964/65, trial II

Planted on : 5.11.64.

Spraying commenced before the onset of infection and sprays were applied at 10 day intervals.

Sprayed on : 12.12, 22.12, 1.1.65, 11.1, 21.1, 30.1 and 9.2.

Fungicide	*Rate 100 gal.*	*Mean % blight at 11 weeks*	*Mean phyto-toxic injury at 11 weeks*	*Mean yield, tons/acre*
Brestan 60	3 oz	0·3	1·0	9·48
Du-Ter	12 oz	0·8	0·5	9·10
Du-Ter + Dithane M-22	12 oz 4 oz	0·1	0·3	10·20
Dithane M-45	2 lb	0·0	0·0	10·46
Manzate D	2 lb	0·0	0·0	11·95
Dithane M-22	2 lb	0·1	0·0	11·02
Lonacol M	2 lb	0·0	0·0	9·83
Mangan Curit	2 lb	0·1	0·0	9·57
Dithane Z-78	2 lb	0·6	0·0	9·92
Antracol	2 lb	0·1	0·0	10·20
Cupravit (Ob 21)	5 lb	0·8	0·8	8·71
Fungicide 328	1¼ lb	1·0	0·0	9·14
Control	—	50·0	—	4·46
L.S.D. (P=0·05)	—	—	—	1·94

TABLE 8—Cost of fungicides applied in spray fluid at the rate of 2 lb./100 gal. and 100 gal. to spray an acre

No. of sprays during season	Total volume of spray fluid required gal	Total weight of fungicide required lb	Cost in Rs. of fungicide for price price range Rs 3–6/lb		
			Rs 4	Rs 5	Rs 66
4	400	8	32	40	48
5	500	10	40	50	60
6	600	12	48	60	72
7	700	14	56	70	84
8	800	16	64	80	96

TABLE 9—Cost of fungicides applied in spray fluid at the rate of 2 lb./100 gal. and 150 gal. to spray an acre

No. of sprays during season	Total volume of spray fluid required gal	Total weight of fungicide required lb	Cost in Rs. of fungicide for price range Rs 3–6/lb		
			Rs 4	Rs 5	Rs 6
4	600	12	48	60	72
5	750	15	60	75	90
6	900	18	72	90	108
7	1,050	21	84	105	126
8	1,200	24	96	120	144

TABLE 10—Economics of fungicidal spraying

Yield increase by fungicidal spraying, tons/acre	Value of increased yield in Rs*	Profit by fungicidal application*†	
		Expenditure on fungicides Rs 40	Expenditure on fungicides Rs 160
2	1,792	1,752	1,632
3	2,688	2,648	2,528
4	3,584	3,544	3,424
5	4,480	4,440	4,320

*Based on the price of potatoes at Rs 896 ton.

†*Appropriate allowance must be made for operational costs where necessary.

TABLE 11—Expression of phytotoxic symptoms

Season	*Trial*	*31–60 days* — *Rain fall* — *Amount in in.*	*Rain days*	*Temperature, °C* — *Av. min.*	*Av. max.*	*Phytotoxic symptoms*
Maha, 1963/64	I	10·14	23	12·5	21·9	Severe
Maha, 1963/64	II	12·63	23	12·2	21·3	Severe
Maha, 1964/65	I	6·86	25	10·9	22·1	Slight
Maha, 1964/65	II	6·40	18	9·3	23·4	Slight

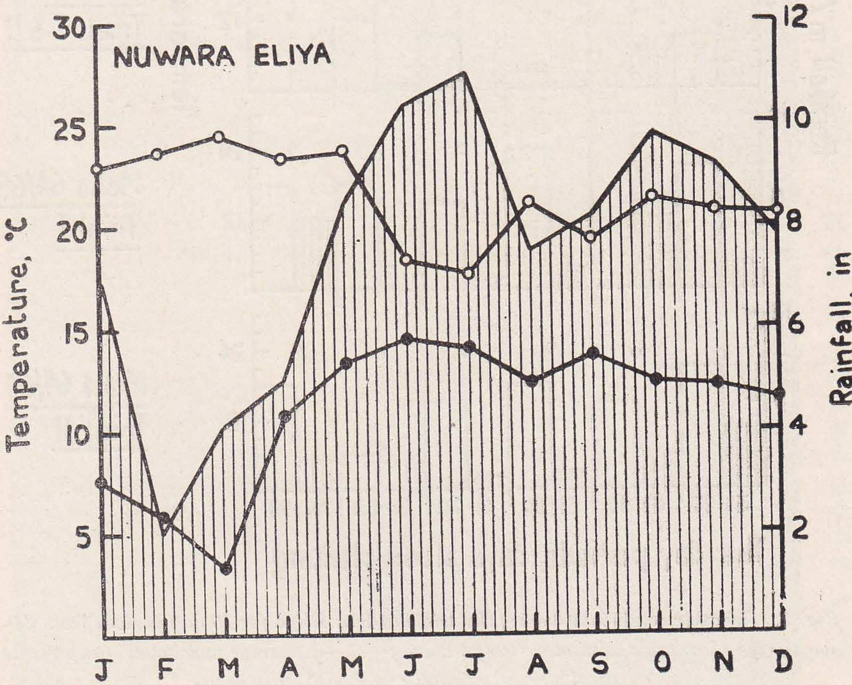

Fig. 1. Temperature and rainfall variation at Nuwara Eliya (hill country wet zone) —●—, mean monthly minimum temperature; —○—, mean monthly maximum temperature; vertical stripes, monthly rainfall.

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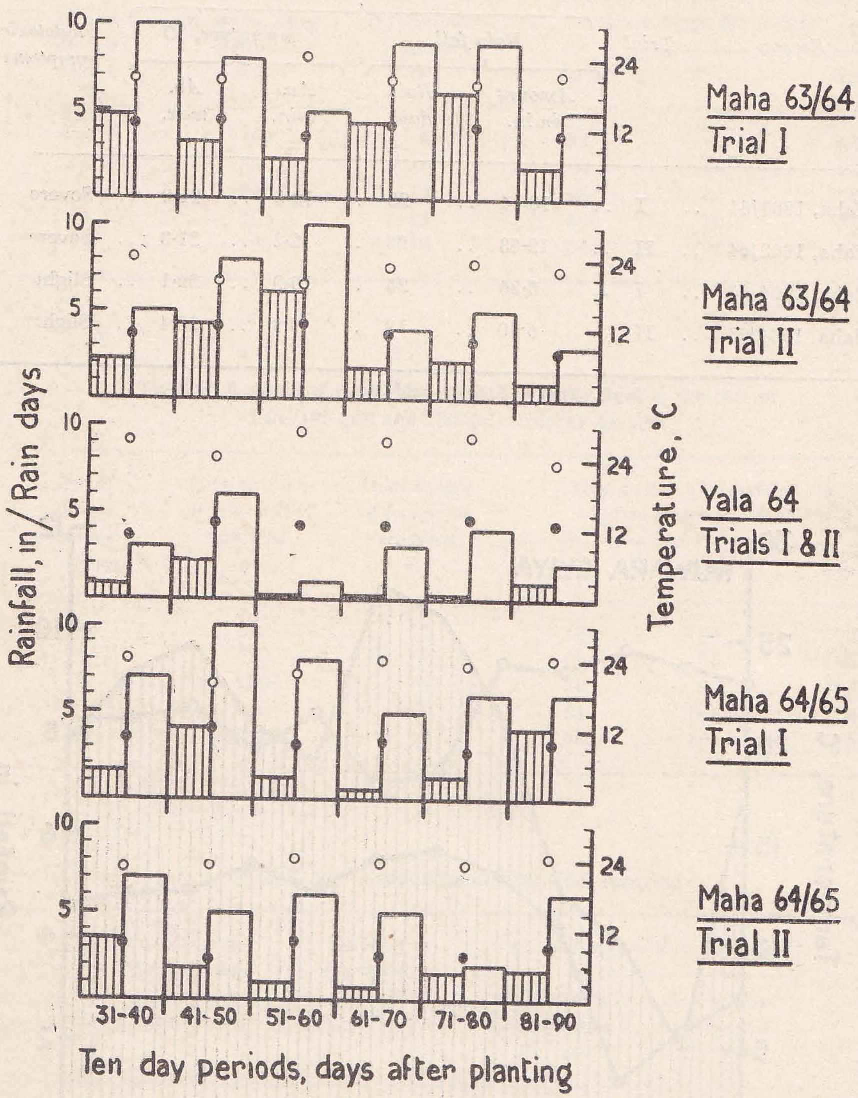

Fig. 2. Weather conditions during the trials at Sita Eliya for 10 day periods from 31–90 days—●—, *average minimum temperature* ;—○—, *average maximum temperature ; vertical stripes, rainfall ; unshaded, rain days.*

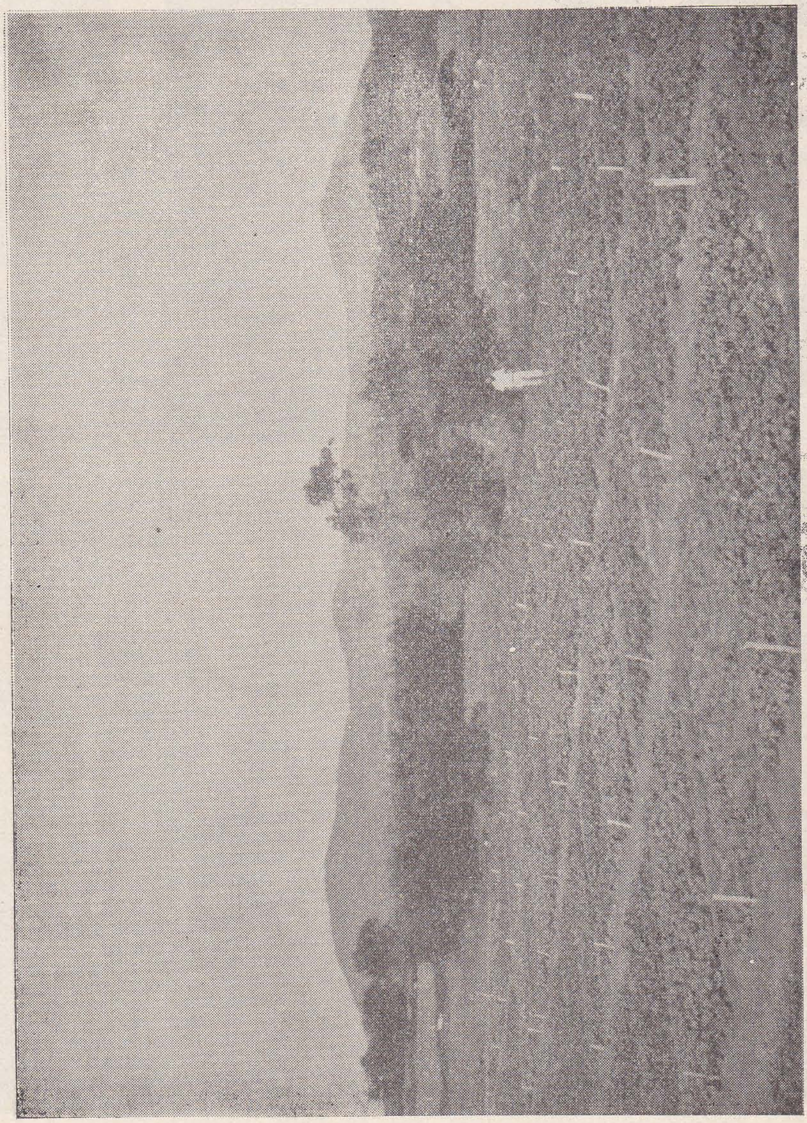

Fig. 3. A general view of a trial. Note the unsprayed control plot in the foreground defoliated by blight.

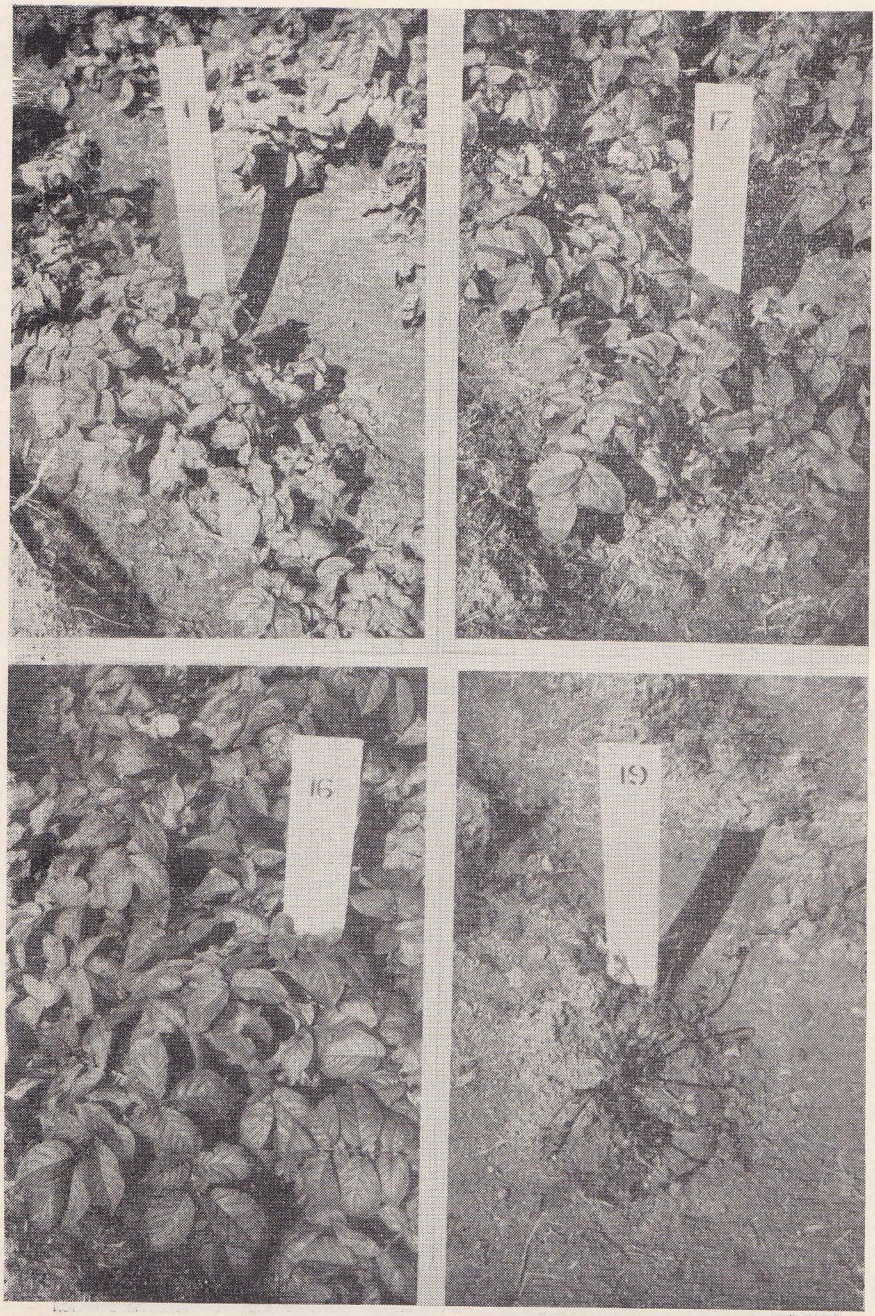

Fig. 4. Treatments from Maha 1963/64, trial II at 65 days after the application of seven sprays. Note the phytotoxic symptoms on the foliage sprayed with organo-tin fungicides which are severe with Brestan 60 (4¼ oz,/100 gal., 7 day interval) (top left, 1) and mild with Du-Ter (1 lb./100 gal. 7 day interval) (top right, 17) in comparison with the healthy foliage sprayed with Dithane M-45 (2 lb./100 gal., 7 day interval) (bottom left, 16) and the defoliated unsprayed control (bottom right, 19).

Study of the feeding value of *Salvinia auriculata* for growing pigs

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INTRODUCTION

Salvinia auriculata which is floating water weed, reported to have been introduced into Ceylon from India, was used extensively during the Second World War as a camouflage for waterways and lakes. Since its introduction, this weed has spread so rapidly that it has become a pest, taking possession of waterways and paddy fields and clogging up irrigation channels. It has also been implicated in the spread of Filariasis in Ceylon. Although a programme for eradication of Salvinia has been existence for some years, this water weed still causes considerable economic damage.

This paper records the results of a study to assess the feeding value of *Salvinia auriculata* for growing pigs. The study was undertaken following a suggestion that Salvinia may be of value as a pig feed. There is no record in the literature on the use of Salvinia as an animal feed. Some work has, however, been reported on the feeding value of a similar water weed, namely, Water Hyacinth (Eichornia crassipes). Water Hyacinth is reported as being a bulky and unpalatable feed, both in the fresh and cooked forms. It is not considered practical to include Water Hyacinth in rations of pigs (Minano, 1938) and in rations of cattle (Chatterjee and Abdul Hye, 1938). More recently, Wahid (1959) has reported the incidence of diarrhoea in cattle, when Water Hyacinth was fed alone.

MATERIALS AND METHODS

A feeding trial was carried out using 3 month old Crossbred (Large White x Large Black) pigs at the Government Livestock Farm, Welisara. Twenty pigs were paired according to the initial weights and treatments allocated at random for each pair. Both groups received a basal concentrate feed made up as follows :—extracted coconut meal 33 per cent., groundnut meal 4 per cent., rice bran (grade I) 30 per cent., maize 20 per cent., wheat flour 5 per cent., fish meal 5 yer cent. and mineral mixture 3 per cent. The quantity of concentrate fed daily was worked out each week on the basis of the weight of pigs in each group. This ration was intended to provide only 75 per cent. of the daily requirement for maintenance and growth. The restriction of the concentrate intake was imposed in order to (1) induce the pigs to consume a reasonable amount of Salvinia and (2) accentuate the differences in the growth response under the two treatments. Group 1 was offered fresh Salvinia while Group 2 received freshly cut Brachiaria brizantha grass on an ad. lib. basis and served as the control group. The amounts of grass and Salvinia offered and rejected were recorded daily. The pigs were weighed at the beginning and thereafter at weekly intervals for the duration of the trial. The experiment lasted ten weeks.

Samples of *B. brizantha* and Salvinia were analysed for crude protein, ether extract, crude fibre, ash and N.F.E. by the conventional methods.

RESULTS AND DISCUSSION

The composition of *B. brizantha* and Salvinia used in the experiment are given in Table 1. It became apparent that feeding of Salvinia in the fresh form would not be the most satisfactory form for feeding, since it contained 95.15 per cent. moisture. However, since pigs would not consume Salvinia in the dried form, there was no alternative but to feed fresh Salvinia.

TABLE 1—Composition of B. brizantha and Salvinia

(as percentages of fresh weight)

	Dry Matter	*Crude Protein*	*Ether Extract*	*Crude Fibre*	*Ash*	*N.F.E.*
B. brizantha	22·76	1·77	0·60	7·69	1·50	11·20
Salvinia	4·85	0·49	0·01	1·60	0·90	1·85

The results of the experiment are given in Table 2 and the growth response of pigs on the two treatments is shown in Fig. 1. At the conclusion of the experiment, pigs on Salvinia showed an average gain in weight of 12.5 lbs. while those on B. Brizantha grass gained 23.1 lbs. The difference in the final weights of pigs in the two groups was highly significant ($P < 0.001$).

TABLE 2

	Group 1	Group 2
Initial weight (lbs.)	26·7	26·7
Final weight (lbs.)	39·2	49·8
Gain in weight (lbs.)	12·5	23·1
Daily intake of Salvinia (lbs.)	1·68	—
Daily intake of B. brizantha (lbs.)	—	2·33

The poor performance of pigs in Group 1 was mainly due to the bulkiness of the Salvinia. The excessive moisture content of Salvinia resulted in a very low dry matter intake. It was also observed that Salvinia was relatively unpalatable. This is evident from the lower intake of Salvinia as compared with B. brizantha. The intake of fresh Salvinia showed a progressive decline throughout the experimental period. The average daily intake of Salvinia was 1.68 lbs. per pig while that of B. brizantha grass was 2.33 lbs. Thus the daily dry matter intake was 0.08 lb. for Group 1 and 0.5 lb. for Group 2. There was no evidence of diarrhoea as has been reported with the feeding of Water Hyacinth to cattle (Wahid, 1959). It is concluded that Salvinia in the fresh state is of no practical value for feeding of pigs.

SUMMARY

The results of an investigation on the feeding value of *Salvinia auriculata* for growing pigs is recorded. Pigs on Salvinia performed very poorly compared to those fed Brachiaria brizantha as part of the daily ration. The authors conclude that Salvinia in the fresh state is bulky and unpalatable and is therefore of no practical value for feeding of pigs.

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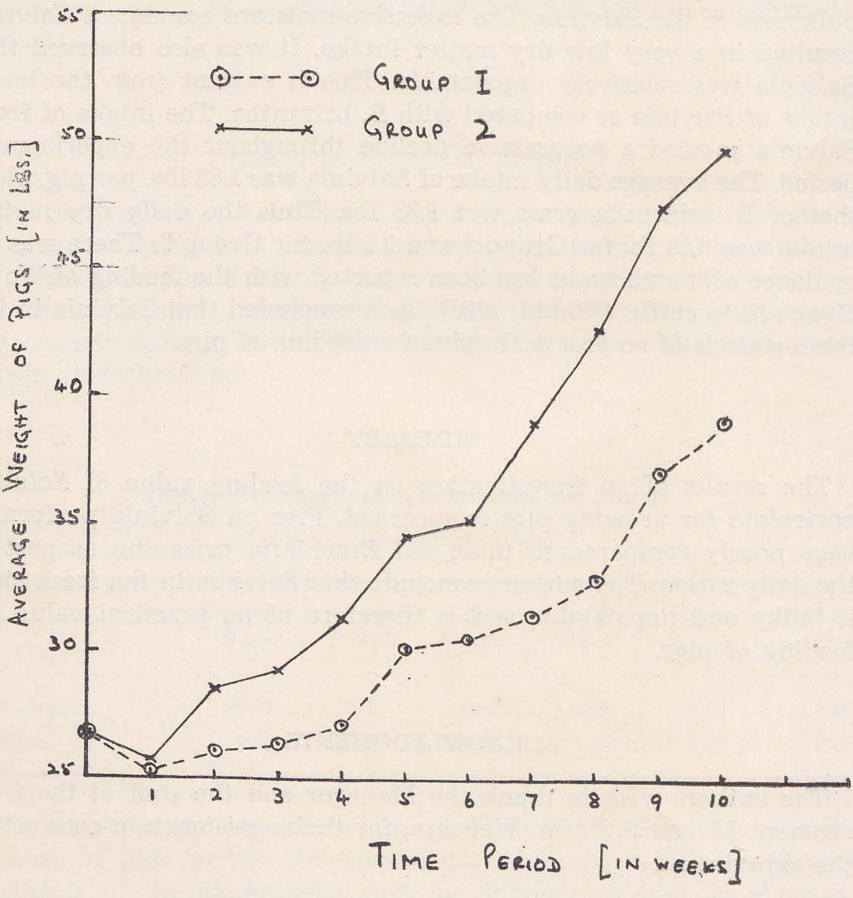
FIG. I – GROWTH RESPONSE OF PIGS ON SALVINIA AND BRACHIARIA



Biennial bearing of mango

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The terms alternate, biennial, intermittent and irregular bearing for mango are usually used by research workers. These terms signify the tendency for mango trees to bear a heavy crop in one year and very little or no crop in the next year. All these terms may broadly be grouped in one general term, viz., "periodicity in cropping".

There are certain varieties of seedling mango which are of shy bearing habit. The terms covering "periodicity in cropping" should not be confused with "shy bearer" or "unfruitfulness", as mango trees are known as shy bearers when they produce a very small amount of fruits instead of the total crop, which should be produced in accordance with proportionate size of tree. On the other hand, they are said to be unfruitful when they produce very little or no crop at all due to factors like unsuitable climate and too humid an atmosphere all the year round.

Trees having a biennial habit bear a heavy crop in one year which is termed "on year" while in the next they bear very little or no crop which is termed "off year". It is a proven fact that this tendency of "on" and "off" remains so and goes on continuously unless the habit is altered by external factors like the occurrence of frost, hail, disease, pests and inclement weather at time of flowering.

For the sound development of the mango industry the production of a reasonably regular crop every year is of prime importance. This is why this review has been prepared to give research workers and orchardists an understanding of the problem.

The discussion of the different factors affecting mango cropping and possible control measures is grouped under different heads in the following review.

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1. *Biennial Bearing Rhythm.*—As early as in the year 1590 Abdul Fazal while giving an account of mango fruit in Ain-i-Akbari mentioned that some trees yielded a heavy crop in a year and light one in the next, while others produced one year and not in the following year. Afterwards it was confirmed that mango trees did not bear a heavy crop only in every alternate year and they produce a poor crop in the intervening year (23). Alternate bearing was found to occur with most trees, but there were interesting exceptions specially among Pirie mango trees. Some workers believe that bearing habit of mango is an acquired character and can be corrected by resorting to proper cultural practices (178). All the factors—cultural practices, growth, flowering, fruit set, and total yield—should be taken into account for bearing habit (120). Mango is a heterozygous fruit and its cropping pattern depends upon the several factors (7, 10, 60, 94, 144, 152, 205).

The mango tree starts the biennial bearing rhythm even from its early stage of fruiting for the first time (90, 157, 160, 208). It was also reported that biennial bearing rhythm sets in at the age of 10 years or more (74). However, Gandhi (43), Singh and Khan (174) reported that young mango bears a regular crop, although not of the optimum quantity every year and later on starts biennial bearing when the trees attain the age of 10 or 12 years.

The measurement of biennial bearing habit in the mango varieties is a very difficult task. It can be assessed through the measurement of the yield of a certain variety on the successive year yield basis for a period of several years. But this scale of measurement seems not to be very accurate for the different sets of trees (11). Hoblyn *et al.* (61) evolved a method to assess the intensity of biennial bearing habit and it has been fully described by Singh (177) for measuring the intensity of biennial bearing in mango. The intensity is calculated for each pair of years by the formula given below.

$$I = \frac{\text{DIFFERENCE BETWEEN SUCCESSIVE YIELDS}}{\text{SUM OF SUCCESSIVE YIELDS.}}$$

Where 'I' stands for intensity of the whole period for a particular tree.

2. *Role Growth Cycle.*—Growth cycle plays an important role in fruiting of mango (168, 198). Vegetative shoots are produced in different flushes and after attaining a certain age they give rise to the

reproductive flush for bearing. These growth flushes emerge in different months in the different parts of the country (43, 143, 207). Burns and Prayag (24) reported that the cold weather, hot weather and rainy season growths produce the inflorescence in western parts of India. Krishnamurthi *et al.* (80) reported 5 cycles of shoot growth in Dashehari and Chausa where main growth flush took place in March to May and 8 to 10 months old shoots were found better to produce better panicles than the younger ones.

Galang and Laza (40) reported that shoots had to attain a certain length, girth, number and size of leaves for producing panicles. However, Singh (200) observed no relationship between length, girth and number of leaves per shoot regarding the flower bud formation as the fruit bud differentiation can take place from any point of the tree and its stimulation is irrespective of the size and maturity of the shoots.

3. *Potentiality of Shoot or Maturity.*—Shoots which appeared early after shedding their blossoms and having desirable extension of growths, have the greater potential to produce panicles in the coming season (21, 114, 118). Mango variety Neelum and Swarnrekha gave rise to shoots as late as October with the potentiality to produce flowers in February (28). However, it has been emphasized that the mango shoots must cease their growths early in order to give rise to flowers in the coming season (72, 115, 164, 173, 175). Shoots which appeared in February-May flush attained the physiological maturity for producing the flower panicles.

Previously the effect of shoot maturity on flowering was emphasized (40, 73, 89, 143, 189) but recently some evidences are found against this theory ; at least in the case of regular bearing varieties, where shoot maturity is not at all a pre-requisite to flowering (44) and the flower formation is governed by the 'off' and 'on' year conditions rather than the age of shoots (178). Singh (200) reported that the types of shoots extended and unextended in biennial bearing varieties form the flower buds in the 'on' year while in 'off' year there is no fruit bud formation in both the types of shoots. 'Off' and 'on' year phase seemed to determine the formation of fruit buds in mango through some special mechanism, in spite of the shoot growth (209).

4. *Fruit Bud Differentiation.*—Fruit but differentiation is a prerequisite stage for the development of a panicle. Chandler (25)

reported that it was not certain to conclude how long a bud sets in a condition that it may be caused to lead to the fruit bud differentiation, while Singh (196) found that the fruit bud differentiation and development is a continuous phase and takes a period of about one month. However, Reece *et al.* (139) observed that differentiation begins within a very short period of the development of terminal buds in mango variety Haden and the process of differentiation goes on continuously with the time of bud expansion.

Lanuza (82) observed no definite floral characteristic to distinguish between a dormant flower and a vegetative bud, while Juliano and Cuevas (69) found that floral parts develop in the order of calyx, corolla, stamens, pistile and finally ovules. Histological and morphological studies made by Singh (199) revealed a clear distinction between flower and a vegetative bud development and its different organs in the order of calyx, corolla, stamen-staminodes, carpel and disc except Baramasi variety.

5. *Time of Fruit Bud Differentiation.*—The times of fruit bud differentiation vary in the different parts of the country (155, 156, 182, 192). In Florida fruit bud differentiation took place in the month of October and November (107, 139, 219). Dry summers are more conducive to flower bud formation in the wet zones (63). Time of fruit bud differentiation ranges from middle of August to end of October in the Punjab (76, 105, 106), Sen and Malik (164) found the critical period of flower bud differentiation in October and first half of November in Bihar conditions while it was noticed after mid-November and reached to its peak by mid-December for Himsagar and by the end of December for Langra in Bengal conditions (162).

6. *Physiological Aspects.*—Flowering is a pre-requisite to fruiting and fruit bud differentiation is pre-requisite to flowering. Fruiting depends on the nutritional status of the particular shoot along with the other factors. Carbohydrate-nitrogen ratios and their increase or decrease content in the shoots play an important role in bearing of mango. For formation of reproductive flush, a mature shoot should have its carbohydrate content much greater in proportion to nitrogen but when nitrogen is more than carbohydrates the shoot will certainly produce vegetative flush. (160).

The problem of biennial bearing should be tackled from the point the physiological changes connected with the emergence of panicles (14). Seasonal variations in the carbohydrate-nitrogen content were studied in Langra shoots by Naik and Shah (117) for the first time. A sharp rise in carbohydrate content in the mango shoots in the period from October to November was reported which was considered favourable for fruit bud differentiation in the mango (89, 166).

Reece *et al.* (138) reported that a flower inducing hormone determines the course of fruit bud differentiation of the tissue. Singh (183, 202) studied the nutritional, biochemical and chemical composition factors of the shoots and found a high content of starch and total carbohydrates at the time of fruit bud differentiation and these appeared to favour the flower-bud formation.

7. *Tree Vigour and Nutrition.*—It is an accepted fact that in the 'on' year the fruits are generally harvested in June-July and thus the trees exhaust their reserve, further to give rise to new shoot growth for bearing fruits in the 'off' year, and the trees cannot replace their reserves since there cannot grow as long as there are fruits on them (11,43). Popenoe (130) observed that crop failures sometimes occur due to the variations of soil moistures and to some extent of food supply, while Roy *et al.* (145) reported that the biennial bearing is caused due to nutritional deficiency which may be brought into order by application of manures. In Florida, Young (241) found that the content of internal nutrition factors and moistures were not the main cause of unfruitfulness in mango variety Haden.

Singh (180), in chemical composition studies of the bearing and non-bearing shoots, found that bearing shoots had higher nutrient value than the non-bearing ones in respect of CaO and MgO in Dashehari and CaO, MgO, N and P_2O_5 in Langra and concluded that biennial bearing in mango is initiated by some factors other than mineral nutrients. Nutritional factor of the shoots cannot be correlated with the fruit bud formation (182), whereas, higher starch reserve, total carbohydrates content and carbohydrate-nitrogen ratio in the mango shoots at the time of fruit bud differentiation was recorded. Singh (202) observed a high content of dry matter linked up with the period of fruit bud differentiation which appeared due to the accumulation of carbohydrates.

Singh (183) reported that biennial bearing of mango is a varietal characteristic and it comprises of strongly biennial, partial beinnial, regular and extra regular. Singh (184) further reported that trees of regular or extra regular varieties are less vigorous than the biennial ones and inferred that vigour is a measure of the biennial bearing habit of the variety and more vigorous in the variety the more biennial tendency it has. It was found that soil group also affected the vigour and cropping behaviour of mango tree (66, 79).

8. *Role of Auxins :—*

(*a*) *Formation of auxins in leaf.*—Auxins are produced in the leaves which are responsible for fruit bud differentiation in mango (138, 139, 153, 156, 189). Chandler (26) is of opinion that hormone induces flowering in plants and the sources of hormone are leaves or some precursor formed in the leaves, then leaf surface rather than accumulation of carbohydrates might be having dominant influence on flowering and further he reported that if hormone or some such substance is necessary for induction of the flower bud, then a fairly definite age and physiological condition of leaf may be necessary for it to induce flowering. Singh *et al.* (206) and Thiman (223) indicated that newly emerged leaves may generate the flowering stimulus in shoots of the regular bearing varieties like Neelum and Romani. Flowering depends on some sort of flowering stimulus transmitted by the leaves to the apical or axillary bud (181). Singh (182) advocated a hypothesis that flower induction can take place only when cell division has started and that a flower inducing hormone plays no part in the initiation of growth but its presence in sufficient amount at the beginning of growth determines the course of differentiation of the tissue in the axillary buds.

Plant growth regulators affect the flowering of mango (163). Singh (186) sprayed G A (50,100 ppm) and M H (0.4-0. 6%) and observed that a crop might be taken by the use of G A even in the 'off' year. Singh and Singh (209) tried NAA, 2, 4, 5-T 2, 4-D (25-500 ppm) and MH (0.05-5. 5%) in Punjab and found that 2, 4, 5-T significantly reduced fruit yield in 'on' year with only small compensation in the succeeding 'off' year while NAA, 2, 4-D and MH showed very little effect on panicle emergence on new shoot growth during the following 'on' year.

(*b*) *Movement of Auxins.*—Flower inducing substance is generally transmitted from the leaves to the axillary buds when inhibiting effect of the terminal bud is removed (138, 139, 156). Singh (181) observed that the flowering hormone used to move in all the directions in stock and by its effect seedlings flower even in the absence of leaves on them. It has been shown that a young mango seedling can be made to flower and fruit, if grafed to a comparable stock of the bearing tree and given additional treatment of defoliation along with the girdling of the scion shoot below the union.

9. *Cytological and Genetical Causes.*—Regular bearing varieties can be evolved to overcome the biennial bearing tendency in mango (19, 91, 100, 114, 190). Besides environmental and physiological factors related to biennial bearing of mango varieties, this factor is controlled by genetic factors. Varieties Dalma, Sukul and others have been found to be regular bearers even under the same soil and climatic conditions in which the majority of them show a characteristic of periodicity of bearing (4, 6, 22, 143, 183, 220). Naik (109) reported that trees of some particular variety in an orchard may be low yielding or sterile while other trees of the same variety in a new orchard may bear heavily.

10. *Sex Ratio.*—The sex ratio plays an important role in determining the crop yield and the varieties producing maximum perfect flowers are usually more prolific bearers (214). In mango, pollination is essential for fruit setting and it is mainly performed by insects (31, 93). Bi-jhouwer (17), Mukherjee (102), Wagle (230) and Singh (195) reported that 50 per cent or more of the perfect flowers remain unpollinated in nature while Spancer and Kennard (217) observed the low fruit set due to failure of gynaecium to develop properly and reduction in the viability of the small quantity of pollen produced by low humidity, high temperature and bright sunlight. The variations were observed in the distribution of perfect flowers on the different portions of panicles, and low or high ratio which lead to the low fruit set in mango (8, 16, 56, 87, 135, 190, 227). However, Naik *et al.* (113) found that many of the flowers are not pollinated at all and the restricted pollinations have adverse effect on the yield. Maheshwari (86) in North India and Popenoe (129) in Florida found that the percentage of flowers which form mature fruits was less than one in mango. Mukherjee (103) found that the failure of pollen germination on stigma might act adversely whereas Naik and Rao (116) obtained better fruit setting by the varietal combinations in pollination in case of South Indian varieties. The essential reproductive organs of the mango flower were observed quite normal and healthy by Mukherjee (99). But Singh (195) reported various degrees of ovule disintegration, while in Florida, Young (24) observed degeneration of embryo sac and in Phillippines Dudgeon (35) observed the loss in fruit set caused by flowers having abortive pistile.

On the basis of sex ratio variety Simmonds and Summer Bahist Chausa were reported for prolific bearing habit (215). Similarly, Ledin (83) reported that polyembryonic-Philippine mangoes are reliable bearers and generally produce heavy yields, often fruiting in clusters. The high percentage of perfect flowers (40 to 80%) probably accounts for the heavy bearing.

11. *Mixed Panicle.*—Production of mixed panicles is favourable for regular bearing in mango (90). Mango varieties showing annual bearing tendency produce a high proportion of mixed panicles than the irregular ones (26, 157). Singh (201) and Randhawa and Damodaran (134) observed mixed panicles in Baramasi and Chausa, Dashehari and Krishna Bhog varieties.

12. *Climatic Factors.*—Climatic conditions may be taken into consideration as some factors which cause the biennial bearing in mango and play an important role in its cropping (27, 33, 104, 147). Climatic factors are associated with the biennial bearing of mango in two ways, either by directly damaging the fruit buds and crop or by creating such conditions which indirectly destroy the flower or fruit. A dry season, immediately preceeding the period of blossom emergence is helpful for early cessation of vegetative growth which is a prerequisite for flowering in mango (52, 62, 93, 111). It was found that, for optimum cultivation of mango, the absence of very low temperature is essential (5, 9, 45, 119).

The drop in temperature during the nights at bloom period inhibits the growth of pollen tube (1, 242, 243). Singh (188) found that when air temperature dropped to 31°F, fruit buds at all stages killed out, and bloom was completely damaged. Formation of buds is affected by a prolonged cold season (57). Frost showed a considerable effect on biennial bearing in the varieties Singhara and Vijai Raogarh (203). Harris (55) observed that the trees often flower profusely but fail to set fruit as the pollen, owing to excessive humidity is never in a suitable condition for cross pollination. Diseases like Blossom Blight during certain years are chiefly responsible for the failure of crop and thus induce irregular bearing (178). In Gautemala, almost all the blossoms were attacked during rainy season (122), while in Florida, disease becomes a limiting factor in rainy or foggy season (235). Insect pests and diseases play an important role for mango drop and they cause severe damage and induce irregular bearing (12, 95, 96, 133, 155). Insects caused 60 per cent to total failure of crop in India (210) and South Africa (6).

13. *Control of biennial bearing*—

(i) *Cultural Practices.* —There is no doubt that planned orchard management plays an effective role for mango cropping. Intensity of alternate bearing can be controlled by a considerable extent with proper planning and orchard management (221, 228). Cultural practices like mulching, cover cropping, irrigation, types of fertilizers and methods of their application also affect the absorption of nutrients and cropping of the mango (59, 85, 91, 144, 225).

Singh (180) suggested that in India mango should be manured during the pre-bloom period also, as alternate bearers are supposed to suffer from malnutrition (46, 88, 145). Ruehle (149, 150) suggested application of N or N and K at the appearance of flower panicles first, followed 3 or 4 weeks later and again during the summer by complete N P K mixtures, as N controls the uptake of other elements and determines growth and shows the greatest effect in combination with P and K. In 'on' years the Ammonium sulphate dose should be doubled to force July-August shoots which mature and flower during the successive 'off' year (92,160). Ledin and Malcolm (84) found that Haden and Zill varieties, fertilized in winter, spring and summer continued to yield more than when fertilized in spring, summer and autumn. Attempts should be made for inducing sufficient vegetative growth early in season of 'on' year by cultural practices (24, 43, 71).

Cultural practices such as root pruning, applications of salt and incission in the bark are also useful (75, 154, 167). Firminger (37) is of view that roots should be exposed for 2-3 weeks in November and covered with fresh earth and manure in December to have some use on biennial bearing habit. A favourable response of cultural practices on flowering and fruiting have been recommended for a good crop as they encounter the biennial bearing in mango (15, 27, 29, 34, 36, 38, 39, 54, 97, 108, 123, 126, 127, 131, 140, 141, 158, 239, 240). Mango crop are some times, severely damaged by insect pest and diseases etc. in the 'on' year and with the result the new shoots appear and give rise to panicles in the next year (13, 77, 110, 121, 137, 211, 212, 213, 233). However, Singh (184) concluded that biennial bearing habit of mango cannot be prevented by restoring to manuring, irrigation, pruning and control of pests and emphasized that the real cause of biennial bearing is not yet known and till it is fully discovered, no 'hit and miss' method is likely to solve the problem ; therefore the first attempt of the scientists, engaged in this field towards the control of this phenomenon will be to determine the exact cause of fruit bud differentiation.

(ii) *Deblossoming.*—Deblossoming early in the season induces the shoots to grow in the same season and produces fruits in the coming season (66, 173, 175). The response to deblossoming appears a varietal feature as Dashehari responds fairly while Langra fails to show the same response (176, 182, 204).

Singh (179) observed that half deblossoming of mango trees as an orchard practice is useful only to the extent of uniform spread of the biennial bearing orchard while Sen (161) advocated that deblossoming, defruiting and branch ringing in 'off' year have response to bearing habit of mango

(iii) *Defoliation and Decapitation.*—Rao and Muthuswamy (136) observed in Mulgoa variety that removal of scion shoots grafted showed its effect as of girdling and decapitating for inducing the axillary buds to differentiate the inflorescence. Defoliation may prove useful as a corrective measure for regulating the bearing in mango as it is cheaper and easier to practice (178,200).

(iv) *Ringing and girdling.*—Ringing or girdling envolves the removal of a ring or bark from the trunk or branches of a tree (88) and this has been practiced for many years particularly in Europe as a means of inducing flower formation (50). Flowering was increased substantially by girdling in October (48, 159). Ringing raised C/N ratio of the branches to force them to flower in 'off' year, and practice was recommended for best results in early August (4). Wagle (229, 231) recommended girdling as a means to obtain flowering in mango.

(v) *Hybridization.*—There is no doubt that periodicity exists in most of the varieties and may be of inherent character, and it may be overcome by evolving new varieties through hybridization (26, 78, 98, 169, 170, 191, 222). Singh (185) suggested that regular bearing species of *mangifera* should be introduced from other countries of the world and interspecific hybridization should be taken up. In North America alone, above 70 research stations were engaged in fruit breeding work. Several new fruit varieties and hybrids have been evolved which have given better performance by way of higher yield, superior fruit quality and resistance to disease and pests (3). In Cuba, Popenoe (128) reports the possibility that occasionally variations may be found due to cross pollination in case of polyembryonic varieties of mango. Singh (207) reports that the hormone are generated by the genes. The remedy will therefore actually lie in regaining the old genetic setup which determines balanced growth and fruiting from season to season and the best way is the evolution of new plant forms through the cross breeding of existing irregularly bearing varieties with the regular ones.

In India as early as in 1885, Lahiri (81) reported that most of the famous varieties of Murshidabad mango had been evolved by cross pollination of Maldha and Choona Khali varieties. Genus Mangifera has allopolyploid nature (101). Taking the base of cytology, Mukherjee (100) concluded that primitive type or types which gave rise to mango varieties originated through allopolyploidy, most probably through amphidiploidy and the further differentiation of the various varieties has taken place primarily through gene mutation (65). Singh and Singh (1940), Roy and Visweswariya (142) are also of opinion that inter-varietal hybridization in nature may be another important factor in the production of new mango varieties. Roy *et al.* (146) recorded even resistance in the hybrid to attack of fruit fly and borer. New early or late maturing mango of high quality with good keeping quality as well as having regular bearing tendency can be produced through hybridization (5, 42, 68, 70, 125, 238). Of 39 varieties originated in Florida, a few have the desirable characteristics of commercial varieties (151). Attempts were made in West Indies to combine the good qualities of Indian Mango with the indigenous types by artificially crossing them (20). In India Burns and Prayag (24) were the first to report artificial crosses from Poona. Naik (112). Sen *et al.* (165), Singh (193), Sturrock (218), Traub and Robinson (224) and Young and Ledin (244) attempted crossing and have produced a few hybrids of promise. Planned hybridization work in India was organized at Kodur (112), Layalpur (148, 172), Sabour (165) and Saharanpur (197). Two promising hybrids, one each of the cross, Neelum x Hymayuddin and Swarnrekha x Jahangir have been evolved at Kodur. Mahumud Bahar and Prabha Shankar hybrids have been evolved from the cross of Bombay and Kalapady at Sabour (146), which have been appealing characters. At Saharanpur, the hybrids of Dashehari and Romani have been evolved which combined in, the good qualities and they are under observations.

Manila from Mexico, Cecil from Cuba, Cambodian and Saigon from Indochina were introduced to Florida : all are polyembryonic and are generally better producers than the Indian mangoes and some like Saigon types are regular bearers and are resistant to anthracnose. The Edward and Simmonds are considered crosses of Haden x Carabao and Semini which is a cross between Saigon-Amini made by Edward-Simmonds of the United States, Plants Introduction Garden in Miami in 1920 (83).

(vi) *Smudging.*—The practice of smudging, depending upon climatic conditions, has been reported as a means to induce flowering. The mango trees are smudged day and night for a week and thereafter in the morning and evening for a month's time. suitable period for smudging is October and December. Smudging heat, not the smoke, helped to induce flowering in non-bearing trees (2, 18, 32, 49, 82, 236, 237). A well planned, research project should be carried out to assess the response of smudging treatments to mango trees (28, 41, 91).

(vii) *Propagation.*—Regular bearing varieties can also be obtained through propagation (30, 31, 47, 132). Role of polyembryony has a good deal of scope and stock from polyembryonic varieties should be taken for the regular bearing varieties (64). In Florida, Brooks, Haden, Eldon, and Smith varieties have been evolved and in Ceylon stocks of certain varieties have been selected for propagation. Besides the utilization of apogamic seedlings has also been recommended by Webber and degree of apogamy in Peach variety is about 100 per cent which is valuable for vegetative propagation (234).

(viii) *Grafting and double grafting*.—The desired change in the bearing habit of mango can be sought through the alternative method of stionic studies (234). Among the root stocks may also be included mango species other than the *Indica* as may be observed to possess the desirable characteristics of growth and regularity in the bearing (207). It has been reported that wild mango Pulima is a very hardy, vigorous one and the trees grafted on it bear profusely and regularly in Ceylon (53). Similarly, Grant and Williams (51) found that 'Thalapat' and 'Saing' varieties have been found to be very good for the grafting of Indian varieties in Burma. Double grafting is believed to suppress excessive vegetative growth of the tree, making it a dwarf and hastening and regulating the bearing. Double worked trees are generally of dwarf habit (28, 58). Singh (182) also observed that dwarf mango trees have generally less tendency towards alternation. This field also needs more intensive research than it has so far received (171).

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METEOROLOGICAL REPORT

Summary for July to December, 1969

JULY : Rainfall during July was below average and absolute drought conditions prevailed at many stations in the northern, north-central and north-western provinces and in the southeast of the Island. Light to moderate rain was experienced over the southwest quarter during the first six days of July. The upper winds weakened considerably from the 7th to the 11th and during this period there was thunder activity over the hills. On the 8th, thunderstorms drifted towards the North, giving moderate rain over parts of the north-central province. From the 12th to the 15th, normal monsoon weather prevailed, scattered showers being confined to the southwest. There was practically no rain over the Island from the 16th to the 21st, due to the upper winds being dry. From the 22nd to the end of the month, scattered monsoon showers were experienced in the southwest quarter, particularly in the hill country, except from the 26th to the 28th, when the weather was mainly fair. The larger monthly totals of rainfall (totals over 10 inches) were experienced over the western slopes of the central hills, particularly the Rozella-Kotmale-Norton Bridge areas. Rainfall over the adjoining area of the southwest quarter ranged from 5 to 10 inches decreasing to 2 to 5 inches over the south-western lowlands and less than 2 inches along the western and southern coastal areas. Over practically the whole of the northern, north-central, north-western and eastern provinces and over part of Uva and the southern province rainfall was below 2 inches, a large number of stations receiving no rain at all. Rainfall was below average over practically the whole Island, except for a few isolated stations. Day and night temperatures were mainly above normal. Day humidity ranged from 54 to 84 percent., while the night humidity ranged from 70 to 92 per cent. Cloud amounts were about or a little above normal and the mean air pressure a little above normal. Wind mileages were above normal at Jaffna and Mannar and below normal elsewhere, the direction being mainly westerly to southwesterly.

August : The drought conditions which prevailed over the northern, north-central and eastern provinces and in the southeast of the island during the past months, ended during August. Rainfall was above average over most of the Island this month. Mild to normal monsoon weather prevailed till the 11th, the rainfall being generally light to moderate, with practically no rain on the 10th and 11th. The upper winds weakened from the 12th and evening thundershowers continued to occur almost daily till the end of the month. The evening thundershowers were fairly widespread on some days and the drought striken areas had appreciable rain. On the 17th, a low pressure area formed over the Island and moved slowly in a northerly direction giving fairly widespread rain. In the southwest, occasional showers were experienced during the latter half of the month resulting in low lying areas and paddy fields being innundated. Other noteworthy weather features during the month were a phenomenal swell of 35 feet reported from Galle on the 4th and a local whirlwind at Anuradhapura on the 23rd, lasting a short time. which caused damage to buildings. The larger monthly totals of rainfall (totals over 15 inches) were experienced over the southwestern lowlands, particularly in the Deraniyagala area and the Neboda-Kalawana areas. Rainfall over the adjoining area of the southwest quarter ranged from 10 to 15 inches decreasing to 5 to 10 inches over the central hills. Over most of the northern, north central and eastern provinces the rainfall ranged between 2 and 10 inches. Rainfall was above average over most of the Island and was below average mainly over the central hills. Day temperatures were mainly about or a little above normal while night temperatures were generally about or a little below normal. Day humidity ranged from 60 to 82 per cent, while the night humidity ranged from 77 to 95 per cent. Cloud amounts were mainly about normal and the mean air pressure a little above normal. Wind mileages were generally below average, the direction being mainly southwesterly.

September: The first four days of September were typical of fairly active monsoon conditions and there was fairly heavy rain in the southwest quarter. From the 5th, the weather improved and generally fair weather prevailed till the 8th. Scattered light to moderate rain was experienced in the southwest quarter from the 9th to the 16th followed by a spell of generally fair weather till the 23rd. Typical inter-monsoonal evening thunder-activity was in evidence from the 24th to the end of the month. The larger monthly totals of rainfall (totals over 20 inches) were experienced inland in the southwest quarter, particularly over the Ginigathhena-Yatiyantota-Watawala areas. Rainfall over the adjoining areas of the southwest quarter ranged from 10 to 20 inches, decreasing to 5 to 10 inches over the southwestern lowlands. Over the northwestern province and over part of the northern province, rainfall was below 2 inches, several stations receiving no rain at all Rainfall was above average mainly over the central hills and generally below average elsewhere. Day and night temperatures were about or a little above normal. Day humidity ranged from 56 to 81 per cent., while the night humidity ranged from 76 to 95 per cent. Mean cloud amounts were about or a little below normal and the mean air pressure about normal. Wind mileages were above normal at Galle and about normal elsewhere, the directions varying from southwest to northwest.

October: Rainfall was above average over most of the Island during October. Mild inter-monsoon weather was experienced during the first four days of the month. From the 5th to the 15th, the weather was under the influence of the Inter-tropical Convergence Zone. Thunder activity was widespread during this period and several places received exceptionally heavy rain. Ratmalana recorded 10.99 inches on the 12th, while Colombo Fort recorded 8.32 inches the same day. St. Leonards on Sea Estate, Elpitiya recorded 8.15 inches on the 14th. A low pressure area developed in the southwest Bay of Bengal on the 15th and there was an extensive area of very bad weather from Madras to Jaffna. On the 19th, due to the upper cyclonic circulation associated with the low pressure area, there was widespread heavy rain, 18 falls of over 5 in ches being recorded. On the 21st, a depression formed in the southwest Bay of Bengal. This later deepened into a cyclonic storm and crossed the Indian coast about 50 miles south of Madras. The upper winds weakened from the 24th and thundershowers inland were a daily feature. From the 26th, thundershowers were widespread, with several fairly heavy falls being recorded. The larger monthly totals of rainfall (totals over 30 inches) were experienced in the southwest quarter over the Yatiyantota and Deraniyagala areas and the southwest coastal belt from Wadduwa to Maggona. Rainfall over the adjoining areas of the southwest quarter ranged from 20 to 30 inches. Over the central hills the rainfall ranged from 15 to 30 inches. Over the northern, north-central and eastern provinces, the rainfall ranged between 5 and 20 inches, and in the southeast between 2 to 15 inches. Rainfall was above average over most of the island, being below average only at isolated stations in the southwest. Day and night temperatures were mostly about normal. Day humidity ranged from 73 to 86 per cent. while night humidity ranged from 84 to 98 per cent. Mean cloud amounts were a little above normal and the mean air pressure little below normal. The wind mileages were below normal, the direction being mainly variable.

November : Generally fair weather was experienced over the Island during the first four days of the month, due to a dry northerly airstream caused by a low pressure area in the South Bay of Bengal. On the 4th the low pressure area deepened into a cyclonic storm and the Inter-tropical Convergence Zone moved northwards to latitude 13 in. North. The Island came under the influence of strong Westerlies and scattered rain was experienced in the south-west till the 8th. Winds around Ceylon became light after the storm crossed the Indian coast. This Cyclone caused devastation in Andra in India. Fairly widespread thundershowers were experienced till the 21st, several heavy falls being reported. On the 17th and 18th, there was heavy rain in the North. 5.50 inches being recorded at Jaffna on the 18th. Thunderstorms activity decreased during the rest of the month, being confined mainly to the hills and the western coastal areas. The larger monthly totals of rainfall (totals over 15 inches) were experienced mainly in the southwest quarter over the Kamburupitiya and Ratnapura areas. Rainfall over the rest of the southwest quarter ranged from 5 to 15 inches. Over the central hills, the rainfall ranged mainly from 2 to 10 inches over the northern province the rainfall ranged mainly between 5 and 15 inches and in the eastern province between 2 and 15 inches. Rainfall was below average over the most of the Island, being above average only at a few isolated stations in the southwest quarter. Day and night temperatures were a little above normal. Day humidity ranged from 67 to 81 per cent., while night humidity ranged from 81 to 98 per cent. Mean cloud amounts were mainly about normal, while mean air pressures were generally a little above normal. The wind mileages were below normal, the direction being variable.

December : The main feature was the extensive floods that were experienced over the Island during the last week of the month. The Southern and Eastern provinces, Sabaragamuwa and Uva and parts of the North-Central Province were the worst affected, large areas being inundated, with some loss of life and severe damage to property.

The weather during the first week of December was predominantly convectional with light winds and an even pressure distribution, most of the rain being confined to the Western and Central regions of the Island. A depression formed in the Bay of Bengal on the 7th near latitude 4 in. North longitude 85 in. East, causing islandwide rain on the 8th and 9th. With the northerly movement of the depression which ultimately filled up on the 14th near latitude 15° North longitude 81° East, the upper winds over Ceylon became westerly to southwesterly from the 11th to the 14th. During this period, weather was mainly fair with a few isolated thundershowers inland and in the East. On the 15th, upper winds were light and fairly widespread thundershowers were experienced.

Northeast monsoon conditions became evident from the 16th and until the 21st, there was light rain in the North and East with scattered afternoon thundershowers inland and in the West.

On the 22nd, a depression was located in the Bay of Bengal centered near latitude 5° North longitude 87° East. There was rain in the East and in the hill country on the 22nd and 23rd. By the 24th, the depression had deepened into a cyclonic storm centered near latitude 8° North longitude 84° East and there was rain over most of the island. On the 25th, the rainfall was heavier, the Minneriya-Polonnaruwa region and parts of Uva experiencing very heavy rain. Minneriya and Hingurakgoda recorded 9.14 inches and 7.80 inches respectively that day. By the 26th, the storm had weakened to a depression, and had moved closer to the Island, being centered near latitude 6 in. North longitude 82 in. East. Kathiraveli in the eastern province recorded 11.45 inches that day. On the 27th, exceptionally heavy rain was experienced in the eastern province, while very heavy rain was experienced over the central, western and southern provinces and Uva. In the eastern province, Sakkaman, Neethai and Rufus Kulam reported over 10 inches while Amparai and Semgapodai reported over 9 inches that day. On the 28th, the southern province and parts of the eastern province continued to experience very heavy rain. Bata-ata and Dandeniya reported falls of over 7 inches that day. On the 29th, the depression was less than 75 miles off the southwest coast of Ceylon near latitude 6° North longitude 79° East and phenominally heavy rain was experienced over the southern province. On that day, there were 16 falls of over 10 inches and 24 falls of over 5 inches in the southern province. The highest rainfall 16.50 inches was reported from Tangalla, while Mawarella and Bata-ata reported 13.97 and 12.62 inches. Several stations reported about 11 inches. It is very probable that these stations too experienced falls of 12 to 15 inches, but due to the rain-guages overflowing after about 11 inches of rain was collected, the true rainfall was not measured. The rainfall experienced on the 29th was the highest on record at the following stations :—

Tangalla	16.50 inches
Bata-ata, Hungama	12.62 inches
Hali-Ela Tank	11.98 inches
West Charley Mount Estate, Denipitiya	11.66 inches
Palatupona Lewaya	11.62 inches
Hambantota Met. Office	11.30 inches
Sirimevana Group, Yakkalamulla	11.28 inches
Mamadola Tank	11.24 inches
Kumana	11.00 inches
Labuduwa Agricultural Station	10.75 inches

On the 30th, the depression moved to a position near latitude 5°N longitude 78°E. Widespread rain continued to be experienced, with the heavier falls occurring in the southern, western, north-central and northern province. Several falls over 5 inches were recorded that day, the highest being 6.72

inches at Nadugala, Matara. The depression was almost stationary on the 31st but weakened, and though rainfall was again fairly widely experienced, it was less intense, no falls of over 5 inches being reported. By the 1st January, 1970, the direct influence of the depression was over, and normal northeast monsoon conditions prevailed over the Island.

The larger monthly totals of rainfall (totals over 30 inches) were experienced over parts of the southern, eastern and north-central provinces and parts of Uva and Sabaragamuwa. Over the remaining areas of these provinces, the rainfall ranged from 15 to 30 inches except for the northern part of Sabaragamuwa where the rainfall was less than 15 inches. In the north, rainfall ranged between 10 and 30 inches and over the north-western province mainly between 5 and 15 inches.

Rainfall was above average over practically the whole Island, only a few isolated stations being below average. Day temperatures were mainly about or a little above normal. Day humidity ranged from 68 per cent. to 87 per cent., while night humidity ranged from 84 to 97 per cent. Mean cloud amounts were a little above normal, while mean air pressures were mainly about normal. Wind mileages were generally a little below average, the direction being northeasterly.

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Director.

Department of Meteorology,
Bauddhaloka Mawatha, Colombo 7,
23rd February, 1970.

July, 1969

Station	Temperature °F				Humidity %		Amount Cloud	Rainfall			
	Mean Max.	Offset	Mean Min.	Offset	Day	Night		Amount	Offset	Rain Days	Offset
Anuradhapura	91·6	+0·7	76·8	+1·0	60	84	6·5	0·10	-1·15	2	-1
Badulla ..	87·3	+1·0	65·0	+0·6	60	92	5·2	1·65	-0·29	6	-1
Batticaloa ..	93·3	+1·5	77·9	+0·9	57	70	5·8	0·12	-1·37	1	-3
Colombo ..	86·6	+1·9	78·1	+1·3	76	84	6·6	1·03	-4·47	6	-9
Diyatalawa ..	78·8	+0·9	62·7	+0·1	61	78	5·0	0·76	-1·55	10	+1
Galle ..	83·3	+0·6	77·4	+0·7	77	82	4·9	1·95	-4·77	12	-7
Hambantota ..	88·6	+1·4	77·5	+1·1	68	84	6·2	0·28	-1·42	4	-3
Jaffna ..	86·1	-0·1	80·1	+0·2	78	82	6·6	0	-0·65	0	-2
Kandy ..	82·6	+·16	70·9	+1·1	66	82	6·5	1·00	-5·08	13	-3
Kankesanturai	90·7	+0·7	80·3	+1·0	67	80	6·0	0·16	-0·57	2	0
Katunayake ..	86·4	—	77·2	—	74	82	6·4	1·13	—	4	—
Kurunegala ..	88·2	+1·9	76·4	+1·2	70	86	6·8	0·38	-4·02	7	-10
Maha Illuppallama ..	91·8	+1·9	76·4	+1·4	60	82	6·1	0·10	—	2	—
Mannar ..	86·4	-0·7	79·2	0	79	85	7·3	0	-0·28	0	-1
Nuwara Eliya	65·1	-0·2	55·5	+0·5	84	88	6·7	3·89	-4·87	21	-1
Puttalam ..	88·1	+1·7	78·5	+0·2	74	89	6·2	0·19	-0·48	2	-1
Ratmalana ..	85·9	+0·8	77·5	+0·7	70	80	6·4	2·49	—	8	—
Ratnapura ..	88·6	+2·0	75·0	+0·7	74	90	6·4	3·65	-8·42	16	-8
Trincomalee ..	94·6	+2·0	79·2	+1·1	54	74	6·6	0·24	-1·89	2	-2
Vavuniya ..	92·8	—	75·9	—	54	79	6·4	1·51	+0·45	2	-1

August, 1969

Station	Temperature °F				Humidity %		Amount Cloud	Rainfall			
	Mean Max.	Offset	Mean Min.	Offset	Day	Night		Amount	Offset	Rain Days	Offset
Anuradhapura	92·0	+0·6	75·4	-0·1	64	88	5·5	3·51	+1·67	12	+7
Badulla ..	86·2	0	65·4	+0·7	67	92	4·6	6·75	+2·97	16	+7
Batticaloa ..	89·3	-1·2	76·8	+0·2	67	77	5·6	3·59	+1·16	8	+2
Colombo ..	86·4	+1·5	76·2	-0·8	78	88	6·1	8·36	+3·49	22	+7
Diyatalawa ..	77·2	-0·7	61·4	-0·4	71	86	5·0	7·25	+3·73	15	+5
Galle ..	83·7	+1·1	76·7	-0·1	77	82	4·7	8·38	+1·34	21	+2
Hambantota ..	84·6	-2·3	76·2	0	78	86	5·8	7·33	+5·67	14	+6
Jaffna ..	86·5	+0·4	78·1	-1·3	78	86	5·4	6·28	+5·04	9	+5
Kandy ..	84·3	+2·2	68·8	-1·0	68	87	5·6	5·37	-0·22	15	+1
Kankesanturai	90·0	0	78·3	-0·8	68	84	4·9	4·35	+2·89	10	+7
Katunayake ..	86·6	—	75·3	—	74	86	5·7	6·45	—	19	—
Kurunegala ..	89·4	-2·6	74·9	-0.1	71	90	6·4	6·24	+1·71	16	0
M'Illuppallama	91·8	+0·9	75·0	-0·1	63	84	5·6	5·13	—	12	—
Mannar ..	87·1	0	78·0	-0·7	78	86	6·4	2·58	+1·95	4	+2
Nuwara Eliya	67·7	+1·5	54·5	-0·1	82	91	6·4	4·70	-2·37	16	-6
Puttalam ..	89·2	+2·4	77·2	-0·8	72	89	5·7	2·12	+1·28	10	+6
Ratmalana ..	86·0	+0·7	75·9	-1·5	71	82	5·8	9·48	—	21	—
Ratnapura ..	88·3	+1·5	73·5	-0·7	78	95	5·6	11·78	-1·12	23	-1
Trincomalee ..	93·6	+1·3	77·9	+0·4	62	78	5·7	3·35	-0·70	8	+1
Vavuniya ..	92·0	—	74·7	—	60	81	5·6	10·73	+8·04	14	+8

METEOROLOGICAL REPORT

Setptember, 1969

Station	Temperature %F				Humidity %			Rainfall			
	Mean Max.	Offset	Mean Min.	Offset	Day	Night	Amount Cloud	Amount	Offset	Rain Days	Offset
Anuradhapura	92·2	0	75·9	+0·7	59	86	5·3	1·35	-1·39	3	-2
Badulla ..	86·8	+1·0	63·6	-0·8	·62	94	3·9	1·71	-1·94	8	-1
Batticaloa ..	91·5	+1·7	76·9	-0·8	66	82	4·3	2·66	+0·78	5	-0
Colombo ..	87·0	+1·7	78·4	+1·9	73	80	5·6	2·19	-3·85	14	-3
Diyatalawa ..	77·9	+0·1	61·6	+0·6	63	81	4·3	2·85	-0·87	10	-1
Galle ..	84·1	+1·3	78·3	+1·5	73	76	4·5	3·54	-3·52	17	-2
Hambantota ..	86·8	+0·4	77·4	+1·2	71	82	4·2	1·25	-0·54	5	-3
Jaffna ..	86·7	+0·4	80·2	+0·7	76	80	5·0	0·25	-1·62	1	-2
Kandy ..	83·1	+1·0	69·8	+2·3	68	85	5·8	4·13	-0·68	13	+1
Kankesanturai	90·7	+0·6	79·3	+0·1	66	80	4·7	0·09	-1·89	1	-3
Katunayake ..	86·9	—	77·3	—	74	84	5·8	1·11	—	12	—
Kurunegala ..	88·7	+0·9	75·6	+1·1	71	91	6·4	2·46	-1·84	15	+1
M'Illuppalama	92·2	+0·2	75·5	+0·6	58	84	5·4	0·73	—	3	-
Mannar ..	87·6	+0·2	79·6	+0·7	76	82	5·7	0	-0·93	0	-2
Nuwara Eliya	66·4	-0·5	54·5	+1·0	81	88	6·0	6·97	+0·47	14	-6
Puttalam ..	89·4	+2·1	79·3	+1·3	71	85	5·1	0	-1·39	0	-4
Ratnapura ..	87·8	+0·5	73·9	+0·4	77	95	6·0	11·25	-1·11	19	-3
Trincomalee ..	95·6	+3·3	78·3	+1·1	57	76	5·0	1·02	-2·48	5	-1
Vavuniya ..	92·1	—	74·8	—	56	81	4·8	1·39	-1·72	2	-4
Ratmalana ..	86·9	+1·1	77·8	+1·2	67	76	5·4	3·19	—	17	—

October, 1969

Station	Temperature %F				Humidity %			Rainfall			
	Mean Max.	Offset	Mean Min	Offset	Day	Night	Amount of Cloud	Amount	Offset	Rain Days	Off set
Anuradhapura	88.3	-1·0	73·5	-0·1	79	95	5·8	20·48	+11·31	25	+9
Badulla	82.2	+0·1	66·2	+0·6	77	95	5·6	8·14	-0·37	22	+5
Batticaloa	86.8	-0·2	75·9	+0•5	78	91	5·6	13•47	+6•46	18	+4
Colombo	97.0	+2·1	75·2	+0·4	77	91	6·3	22•01	+8·07	24	+3
Diyatalawa	75.2	-1·3	61·1	+0·4	81	94	5·4	11•57	+1·80	23	+4
Galle	84.2	+1·3	75·4	+0·1	74	84	5·6	19•52	+5·50	21	0
Hambantota	85.6	-0·5	75·8	+0•3	76	86	5·6	11•48	+6•53	16	+3
Jaffna	85.9	+0·1	77·0	+0·8	80	88	6•0	11·91	+2·32	22	+9
Kandy	84.2	-1·0	68·6	+0·6	74	90	5·8	18·66	+8·48	24	+7
Kankesanturai	87.1	-0·2	76·2	-1·1	74	88	5·8	12·02	+3·29	18	+7
Katunayake	86.8	—	73.6	—	80	98	6·0	30·21	—	26	—
Kurunegala	88.2	+0·9	73.2	-0î1	77	95	6·2	19•86	+6·87	25	+5
M'Illuppalama	88.4	-0·9	73.1	-0î1	74	90	6·4	12·77	—	22	—
Mannar ..	87.0	+0·4	76 ·8	-0î6	79	88	6·8	11·59	+4·99	17	+6
NuwaraEliya..	68.4	+0·7	52·9	+0î5	86	91	6·2	11·82	+3·07	25	+4
Puttalam ..	87.8	+1·2	75·3	-0î5	78	93	6.0	16·05	+9·21	21	+8
Ratnapura ..	88.9	+1·7	72·6	+0î2	80	95	6•1	18·10	-1·52	26	+3
Trincomalee ..	87.7	-0·6	75·5	-0î3	74	86	6·2	16·47	+4·23	23	+7
Vavuniya ..	88.0	—	72·6	—	73	88	6·2	19·07	+10·29	25	+10
Ratmalana ..	86.3	+C•9	74·2	-0î9	70	86	6·2	24·35	—	24	—

Novembei, 1969

Station	Temperature °F				Humidity %		Amount Cloud	Rainfall			
	Mean Max.	Offset	Mean Min.	Offset	Day	Night		Amount	Offset	Rain Days	Offset
Anuradhapura	87·0	+1·2	72·5	+1·0	77	93	5·2	5·90	-3·88	22	+3
Badulla ..	81·5	+2·1	65·8	+0·3	75	95	5·3	2·80	-7·72	14	-6
Batticaloa ..	85·2	+1·0	75·1	+0·8	77	91	5·8	6·28	-4·95	16	-2
Colombo ..	86·5	+0·3	74·2	+0·9	73	88	5·5	10·06	-2·71	15	4
Diyatalawa ..	73·7	-0·7	60·2	+0·4	81	94	5·8	6·37	-4·57	23	+1
Galle ..	84·8	+1·2	74·9	+0·7	72	81	4·8	8·60	-4·09	20	+1
Hambantota ..	85·4	—	74·7	+0·6	76	88	5·6	3·38	-4·00	14	-1
Jaffna ..	85·6	+1·5	75·2	+0·3	75	88	5·5	14·34	-1·85	13	.5
Kandy ..	84·0	+1·2	67·9	+0·5	70	90	5·6	4·33	-5·50	15	-2
Kankesanturai	85·3	+1·3	75·3	-0·3	76	86	5·2	11·62	-4·46	15	-1
Katunayake ..	88·0	—	72·7	—	76	98	5·5	8·79	—	14	—
Kurunegala ..	88·1	+1·3	72·1	+0·3	74	98	5·8	5·30	-5·78	14	-5
M'Illuppallama	86·9	+1·3	72·0	+1·0	72	90	5·6	4·46	—	17	—
Mannar ..	86·0	+1·6	76·3	+0·5	77	86	5·8	5·52	-4·04	12	-5
Nuwara Eliya ..	68·5	+0·7	52·4	+1·0	79	91	5·8	5·59	-2·62	16	-5
Puttalam ..	87·1	+1·3	73·8	+0·6	76	95	5·2	6·50	-3·54	14	-4
Ratmalana ..	86.9	+0·6	73·5	+0.3	67	86	5·6	10·45	—	18	—
Ratnapura ..	89.8	+2·0	72·0	-0.2	76	95	6·0	7·60	6·32	19	-2
Trincomalee ..	85.3	+1·6	75·3	+0·4	75	86	5·8	13·72	-0·26	19	0
Vavuniya ..	87.4	—	71·8	—	70	85	5·5	5·70	-5·85	17	-1

Decembei, 1969

Station	Temperature OF				Humidity %		Amount Cloud	Rainfall °F			
	Mean Max.	Offset	Mean Min	Offset	Day	Night		Amount	Offset	Rain Days	Offset
Anuradhapura	83·9	+0·6	72·3	+2·0	84	95	6·3	15·12	+5·88	22	+5
Badulla ..	78·3	+1·7	66î4	+1·7	84	95	6·8	21·19	+10·37	26	+6
Batticaloa ..	82·6	+0·6	74·3	+0·5	84	93	6·1	32·17	+15·25	25	+5
Colombo ..	85·5	-0·1	73·9	+1·5	78	90	5·8	16 ·81	+9·93	14	+2
Diyatalawa ..	72·0	-0·1	60·7	+1·8	87	97	6·4	15 ·61	+7·60	25	+5
Galle ..	84·7	+1·1	73·9	+0·5	73	86	5·5	21·78	+14·47	19	+5
Hambantota ..	85·4	+0·6	74·1	+0·9	76	88	5·8	19·18	+14·37	15	+3
Jaffna ..	82·5	-0·1	74·4	+1·1	81	90	6·3	16·94	+6·44	21	+7
Kandy ..	82·2	+0·5	67·8	+1·9	74	90	6·0	9·63	+1·34	22	+9
Kankesanturai	82·5	-0·4	74·9	-0·4	82	88	6·2	19·00	+8·75	22	+9
Katunayake ..	86·7	—	72·7	—	78	95	5·8	13·76	—	18	—
Kurunegala ..	86·3	+0·7	72·1	+1·3	77	95	5·8	10·00	+3·05	19	+5
M'Illuppalama	84·2	+0·4	72·0	+2·2	78	90	6·0	13·78	—	21	—
Mannar ..	83·0	+0·4	75·4	+0·4	82	88	6·6	15·71	+7·74	20	+6
Nuwara Eliya ..	67·0	-0·7	53·4	+3·9	87	94	6·4	14·35	+6·84	23	+3
Puttalam ..	85·0	+0·1	73·1	+1·7	81	95	5·7	7·46	+1·42	22	+9
Ratmalana ..	86·0	-0·7	73·0	+1·0	68	84	5·6	16·94	—	16	—
Ratnapura ..	88·6	+0·5	72·2	+0·5	80	95	6·6	9·37	+0·96	21	+5
Trincomalee ..	83·1	+1·9	75·2	0	80	86	6·6	25·14	+10·42	27	+9
Vavuniya ..	83·7	—	71·5	—	74	85	6·4	17·23	+6·31	24	+8