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Use of Silkworm (*Bombyx mori L.*) Pupae as a Protein Supplement in Poultry Rations

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(*Paper accepted* : 18 *May* 1977)

Abstract : An investigation was conducted to find the effect of various levels of replacement of local fishmeal with silkworm pupae (SWP) on the performance of broiler starters, broiler finishers and laying hens. The results indicated that SWP could successfully replace local fish-meal in poultry rations. The presence of an unidentified growth factor in SWP for chicks was also observed. Improvement in reproductive performance in terms of hatchability of eggs and weight of chicks at hatching time were observed when SWP was included in layers rations. A favourable alteration of the sex ratio in chicks towards feminity was observed.

1. Introduction

Little work has been done in Sri Lanka, to replace the traditional animal protein supplements in animal feed with by-products of agro-industrial origin. In silk manufacture, silkworm pupae (SWP) are discarded as a by-product during the reeling operation. At this stage, however, they are surrounded by a tough, chitinous covering of a gluco-proteinous material which must be removed before utilization for animal feeding.[6] With the rapid expansion of the sericulture industry in Sri Lanka it is expected that a large quantity of SWP would be available as a by-product. Both dry and wet methods have been employed for the removal of this chitinous covering. In the dry method, mechanical cutting, crushing and sifting is carried out in order to separate the chitin from pupal matter. In the wet methods, boiling is done either in water or in a dilute solution of caustic soda to soften the chitin, which is then peeled off mechanically or manually.[2]

The pupal matter that remains after the separation of the chitinous covering contains a high percentage of protein and oil. The pupal oil contains nearly 75% unsaturated fatty acids which has valuable industrial uses.[2,6] Both SWP and pupal residue after oil extraction have been used as animal feeds for chicken, pigs, rabbits and cattle and also as a food for freshwater fish.[2] The presence of large quantities of unsaturated fatty acids imparts a peculiar smell to the SWP and it is generally believed that flesh or eggs of animals fed on undefatted SWP have an unpleasant odour for the same reason.[1,2] However, this phenomenon was not observed in the investigations carried out by Habe *et al.*[1] and Yoshimura,[5] using undefatted SWP. Today, there are a number of patented biological and chemical methods for the deodourization of SWP. No attempt was made to deodourize or defat the pupal matter used in the investigation reported here. It was attempted in this study to evaluate the possibility of replacing local fishmeal with silkworm pupae in broiler starters, broiler finishers and layer rations.

2. Materials and Methods

2.1. Materials

A consignment of dried silkworm pupae with their chitinous coverings was obtained from the Central Sericulture Station, Pallekelle, Sri Lanka. This product was compared with Grade I fish meal produced locally.

2.2. Preparation of SWP

The pupae were first ground (in a feed grinder) to tear open the chitinous coverings and to release the enclosed pupal matter that was powdered in the process. The chitinous matter was then manually separated from the pupal powder. The turn out of the latter from this process was about 46%. This method is simple and involves no loss of soluble nutrients as in the wet methods. In order to obtain the maximum recovery, manual separation, although cumbersome, needs to be carried out carefully.

2.3. Chemical Analysis

The pupal material and the fish meal were analysed for major nutrients according to the methods recommended by the Association of Official Agricultural Chemists.[4] These analytical values are reported in the Table 1. The calcium and phosphorus levels were analysed spectrophotometrically. Amino acid analysis was done with the assistance of Dr. T. Kurose of Japan, using JLC-AH, Nihon Denshi (JEOL) automatic amino acid analyser.

TABLE 1. Chemical composition of Silkworm Pupae and Fish meal (%).

Constituents	Silkworm Pupae	Fish meal
Moisture	8.50	17.40
Ether Extract	19.47	2.77
Crude Protein	63.30	40.10
Crude Fibre	3.10	2.80
Ash	4.50	35.90
Nitrogen free extract	1.13	1.03
P_2O_5	2.03	—
$CaCO_3$	0.545	—

2.4. Feeding Trials

Three feeding trials, viz. I, II and III were conducted using broiler starters, finishers and layers, respectively. The experimental rations were balanced to carry nutrients according to the recommendations of the National Research Council of USA.[3] These rations were compared with the control rations in each trial (Table 3), containing local fish meal as the main source of animal protein.

2.5. Feeding Trial I

Experiment I, consisting of six treatments, was designed to test SWP in broiler starter rations (Table 2). The first four diets were formulated to be iso-caloric and iso-nitrogenous. The control ration (1) carried 15% local fish meal. The experimental rations 2 and 3 carried 10% and 12% SWP, respectively. SWP was the only source of animal protein in the diet 3. Ration 4 was the same as Ration 3 except that the former carried 60 grams (2 ounces) of lysine per 50 kg of the ration. Rations 5 and 6 were formulated to determine the possible presence of an unidentified growth factor in SWP. Ration 5 was balanced above the recommended nutrient requirements for starter chicks. Ration 6 was made by mixing 100 parts of Ration 5 and 5 parts of SWP.

The above rations were fed in mash form to one week old, Cornish × White Rock broiler starter chicks for a period of five weeks. Every treatment was replicated twice and carried 10 chicks in each. The replicates were arranged in a randomized block design. All chick groups were equalized for weight initially and were raised in a Multiplo Battery Brooder during the entire experimental period. Feed and water were provided *ad libitum*. Observations were made on weekly weight gains (G) and feed consumption (F). From the data thus obtained, the average of the weekly feed efficiency $\left(\frac{F}{G}\right)$ was calculated.

TABLE 2. Amino acids in protein extracted from Silkworm Pupae.

Amino Acid	Mass g/100g protein
1. Alanine	3.89
2. Arginine	4.62*
3. Aspartic acid	8.65
4. Cystine	0.35
5. Glutamic acid	8.65*
6. Glycine	3.46*
7. Histidine	2.25
8. Isoleucine	3.77*
9. Leucine	6.02*
10. Lysine	5.31*
11. Methionine	1.75*
12. Phenylalanine	4.25*
13. Proline	1.60*
14. Serine	3.68
15. Threonine	3.83*
16. Tyrosine	4.80
17. Valine	4.59*
18. Ammonia	1.35
Total Recovery	73.29

*Amino acids essential for chicken.

TABLE 3. Percentage composition of rations used.

Ingredients	EXPERIMENT I					EXPERIMENT II					EXPERIMENT III	
	Control		Experimental Diets			Control	Experimental Diets				Control	Exp. Diets
	1	2	3	4	5	6	1	2	3	4	1	2
Corn	49.00	50.00	50.50	50.50	46.00	46.00	60.00	62.00	62.00	62.00	56.5	59.5
Rice Bran	—	1.50	4.00	4.00	—	—	—	1.00	1.00	1.00	—	—
Gingelly poonac	12.00	12.00	12.00	12.00	12.00	12.00	15.00	15.00	15.00	15.00	8.00	8.00
Coconut poonac	18.00	18.00	18.00	18.00	12.00	12.00	10.00	10.00	10.00	10.00	20.00	20.00
Fish meal	15.00	—	—	—	15.00	15.00	10.00	—	—	—	10.00	10.00
Skim milk powder	5.00	5.00	—	—	15.00	15.00	5.00	5.00	2.50	—	2.00	—
Silkworm pupae	—	10.00	12.00	12.00	—	5.00	—	5.00	7.50	10.00	—	7.5
Bone meal	1.00	3.00	3.00	—	—	1.00	1.00	1.00	1.00	1.00	1.10	2.5
Shell powder	—	0.50	0.50	0.50	—	—	—	1.00	1.00	1.00	2.5	3.5
Lysine	—	—	56 gm	56 gm	28 gm	28 gm	—	—	—	—	2.5	3.5
Methionine	28 gm	—	—	—	28 gm	28 gm	—	—	—	—	—	—
Vitamin Premix	100 gm	100 gm	100 gm	100 gm	100 gm	100 gm	100 gm	100 gm	100 gm	100 gm	100 gm	100 gm
Coccidostat	100 gm	100 gm	100 gm	100 gm	100 gm	100 gm	100 gm	100 gm	100 gm	100 gm	100 gm	—

2.6. Feeding Trial 2

Experiment II included four treatments and was designed to test SWP in broiler finisher rations (Table 2). The control ration (1) carrying local fish meal at 10% level was compared with Rations 2, 3, and 4, carrying 5%, 7.5%, and 10% SWP respectively.

The above rations were fed to six weeks old Cornish × White Rock, broiler finisher chicks for a period of five weeks. The experimental design followed in this experiment was similar to that of Experiment I. Here the birds were housed in colony cages during the entire experimental period. Weekly weight gains and feed consumption were recorded. Feed efficiency was calculated from the data thus obtained. At the conclusion of the experiment, 3 birds from each replicate were slaughtered and dressed to estimate the carcass recovery percentage.

2.7. Feeding Trial 3

Experiment III was designed to test SWP in layer rations and to study its effects on egg production, egg weight, egg quality, shell thickness, egg palatability, fertility, hatchability, weight and percentage of normal chicks at hatching time and their sex ratio. This experiment consisted of two treatments. The Treatment 1 which was the control ration carried 10% local fish meal and the Treatment 2 which was the test ration 7.5% SWP, without any fish meal (Table 2). The treatments were replicated twice and each replicate carried eight, one year old White Leghorn hens which were housed in individual battery cages. The hens were artificially inseminated twice a week, using pooled semen collected from cock birds maintained on a commercial diet. The experiment was conducted over a period of six weeks. During this period egg production and individual egg weight were recorded daily and the feed consumption on a weekly basis. Feed efficency was then calculated to express the amount of feed consumed per dozen eggs produced. Except during the first week of the experimental period, shell thickness and albumen height were measured in six eggs taken at random from each replicate, every week. Using egg weight and albumen height, Haugh Index was calculated as a measure of internal quality of eggs. In order to find out any differences in palatability, flavour and odour, a representative number of eggs from both treatments were hard-boiled, halved and served to a taste panel. Eggs were hatched weekly after the first week from the commencement of the trial and for five weeks. Candling of incubated eggs was carried out every 7th and 14th day of each incubation and fertility was calculated :

$$\% \text{ Fertility} = \frac{\text{Number of fertile eggs} \times 100}{\text{Number of eggs set}}$$

At the end of each incubation, the number of chicks hatched out was estimated to calculate the hatchability =

$$\frac{\text{Number of chicks hatched} \times 100}{\text{Number of fertile eggs}}$$

The percentage of normal chicks at hatching time was also recorded. The chicks were sexed by the vent sexing method and the sex ratio for each treatment was recorded.

3. Results

3.1. Chemical Analysis

Table 1 presents the proximate analysis of SWP and fish meal. The amino acid composition of SWP is given in Table 2. SWP was higher in dry matter, protein and fat content when compared to the locally produced fish meal, but relatively low in total ash and in calcium and phosphorus.

3.2. Feeding Trial 1

The total and weekly weight gains, total feed consumption and the average feed efficiency of Experiment I are given in Table 4. Here the weekly as well as the total weight gains of chicks on Ration 6 were superior to those on all other rations throughout the entire experimental period. ($P = 0.01$). Rations 3 and 4 were not significantly different from the control. Also the Rations 2, 3, 4, and 5 were not significantly different from each other.

TABLE 4. Weight gains, feed consumption, and feed efficiency of Experiment I

Treatments		Total Weight Gains (g)	Total Consumption (g)	Average Feed Efficiency
Control	1	1071.00	4323.5	4.00
	2	2050.50	5379.4	2.55
	3	1484.75	4024.7	3.05
	4	1561.75	4553.2	2.85
	5	1960.25	4984.9	2.67
	6	3776.50	7772.9	2.22
Least Significant Difference	5%	808.02	1585.15	0.81
	1%	1223.57	2400.37	1.24

Feed consumption of birds on Ration 6 was significantly superior to those on Ration 2 at (P = 0.05) level and to all other groups at (P = 0.01). There were no significant differences among Rations 1 to 5.

Ration 6 had the highest feed efficiency. The feed efficiency of Rations 2 to 5 were significantly (P = 0.05) superior to the control, but there was no significant difference between them.

3.3. Feeding Trial 2

In Experiment II, Rations 2, 3 and 4 were significantly (P = 0.05) superior to the control in terms of total weight gains, feed consumption and average feed efficiency for the entire experimental period (Table 5). Rations 3 and 4 did not differ significantly in both weight gains and feed consumption. Feed efficiency of birds on Rations 2 and 3 and birds on Rations 3 and 4 did not differ significantly. Ration 2 however was significantly (P = 0.05) superior to Ration 4 in feed efficiency. Carcass recovery percentages have been increased with the increase in the SWP in rations, except for the Treatment 2. Ration 4 containing 10% SWP gave the highest increase in recovery percentage, which was superior to the rest of the rations at a statistical significance of 1% level.

TABLE 5. Weight gains, feed consumption and feed efficiency and carcass recovery percentages—Experiment II.

Treatments		Total Weight Gain (g)	Total Feed Consumption (g)	Average Feed Efficiency	Carcass Recovery percentages
Control	1	3773.00	13,588	3.97	68.80
	2	5096.00	15,442	2.90	67.55
	3	5796.00	17,976	3.03	69.75
	4	5936.00	18,452	3.13	70.85
	5	—	—	—	—
	6	—	—	—	—
Least significant Difference	5%	187.57	1581,60	0.153	1.56
	1%	310.27	2617,03	0.253	2.58

3.4. Feeding Trial 3

In Experiment II, differences were observed between the control and the test ration, in terms of total egg production, feed consumption, feed efficiency, average egg weight and egg quality, and shell thickness (Table 6). On the other hand most of the measurements of character associated with reproductive performance, obtained for the test ration were significantly superior to those on the control ration (Table 7).

Significant (P = 0.05) differences were seen in percentage hatchability and in average weight of chick at hatching time. There were no significant differences in percentage fertility and percentage normal chicks at hatching time. Assuming a null hypothesis of 1 : 1, the "Chi-Square" test was applied on the total number of male and female chicks obtained for each treatment. The deviation observed in the control ration did not differ significantly from the expected values. However the deviation observed in the test ration differed significantly (P = 0.01) from the expected values. The sex ratio in chicks was altered favourably by the inclusion of SWP in a layers ration, with an increase in the number of female chicks over the number of males.

TABLE 6. Effects of SWP on the performance of laying hens, during 6 weeks of experimental period.

Treatment		Total egg production (Nos.)	Total feed consumption (kg)	Feed Efficiency for a dozen of eggs	Average egg weight (kg)	Egg quality (Haugh Units)	Shell Thickness (× 0.0025cm)
Control	I	156	31.38	2.76	58.85	86.88	0.034
	II	175	33.64	2.41	57.4	86.19	0.032

Statistically not significant.

TABLE 7. Effects of SWP on hatchability, fertility, hatch weight, vigour and sex ratio at hatching time.

Treatment		Average hatchability	Average fertility	Vigour at hatching time	Hatch weight of chickens	Sex Ratio	
						Male	Female
Control	I	65.63	84.7	86.80	44.05	48±	52±
	II	78.57	85.7	94.07	40.92	64*	36*
Least Significant Difference	5%	9.80			2.37		
	1%	22.62			5.46		

* Statistically significant

± Statistically not significant.

4. Discussion

The results of Experiment I suggest that local fish meal could be successfully replaced by SWP upto 12% level. Weight gains of birds on Ration 2 over those on the control were superior by about 48%. This was probably due to the higher biological value of the mixture of proteins in Ration 2 which contained both SWP and skim milk powder. Lack of significant differences between Rations 3 and 4 shows that lysine supplementation of SWP containing rations when the SWP is used as the only

source of animal protein, is not essential. The lack of significant differences between Rations 3 and 4 and between the control ration indicates that SWP could successfully replace fish meal and skim milk powder in chick ration. This finding is strengthened by the fact that the nutritive value of SWP protein when compared with casein is 134%.[6] The extremely superior weight gains, feed consumption and feed efficiency of birds on Ration 6 over those on Ration 5 during the entire experimental period, resulting in an increase in total weight gains by about 48%, indicates very clearly that there is an unidentified growth factor for chicks in SWP.

Results of Experiment II point out that SWP could successfully replace local meal in broiler finisher rations either in combination with skim milk powder or when used as the only source of animal protein. The superior performance of birds on Ration 2 over those on Ration 4 confirms the complementary combining effect of SWP and skim milk powder, which was observed in Experiment I.

In Experiment III, the absence of significant differences in egg production, egg weight, egg quality may be because of the fact that SWP when used at 7.5% level in the test ration supplied adequate amounts of amino acids and protein equivalent to the 10% local fish meal plus 2% skim milk powder. However, Sakia *et al.*[5] report that inclusion of SWP in layer rations improved feed efficiency and egg weight, and reduced mortality and increased egg laying.[7] The maintenance of adequate levels of calcium in SWP containing ration is the reason for the lack of significant differences in the shell thickness. The participants of the taste panel were unable to detect any differences in flavour, odour or palatability in eggs from the two treatments. Similar results have been reported by Habe *et al.*[1] and Yoshimura.[7] It is likely that the influence of SWP on the flavour, odour and palatability of animal products depend on the level of inclusion of this material in rations. The improvement of reproduction performance in birds fed on SWP containing diets have also been reported by Yoshimura.[7] These findings were evident in the present investigation in which the inclusion of SWP in a layers ration improved hatchability, average weight of chick at hatching time and femininity in chicks hatched out.

5. Conclusions

The results of the three trials undertaken in this investigation to test the feasibility of using SWP in poultry rations indicate that it can be used in place of local fish meal, as a source of animal protein in chick starter, broiler finisher and layer rations. A higher level of calcium and phosphorus needs to be maintained in rations carrying SWP. In view of the improvement in reproductive performance observed in this study and in studies carried out elsewhere, it would be particularly useful to include SWP in breeders rations. In order to enable poultry farmers to use this material as a protein supplement in feeds, the price of SWP needs to be more realistic than at present.

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References

1. HABE, *et al.* (1937) *Report on Animal Husbandry Station.* **12**.
2. KUROSE, T. Personal communications.
3. National Research Council of U.S.A. (1966) *Nutrient requirement of Poultry Publication.* **1345**.
4. *Official methods of analysis of the Association of Official Agricultural Chemists* 1965. Tenth Edition..
5. SAIKIA, A., DAS, P. C., & SUTRADHAR, R. (1971) *Systematic study of by-products of agro-industrial origin for evolvement of economic poultry rations—layers rations. Indian Vet. J.* pp. 941-946.
6. SAINI, S. Y. P. (1975) *Multipurpose silkworm pupae.*
7. YOSHIMURA, T. (1933) *Sangyo-Simpo.* **476**.

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Some Observations on the Grazing Behaviour of European Cattle in the Mid-Country of Sri Lanka

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Abstract : Two studies, namely a barn study and a field study were carried out to acquire knowledge on the behaviour of exotic dairy cattle in the mid-country of Sri Lanka. Observations on behaviour patterns were carried out with six milking cows, two from each breed: Fresian, Ayrshire and Jersey, at the Experimental Dairy Unit of the Department of Animal Husbandry, University of Sri Lanka, Peradeniya Campus. The average time spent in zero-grazing in the barn and free-grazing in the field was 8.80 h and 9.55 h per day, respectively. The corresponding grazing to rumination ratios (G/R) were 1.47 and 1.34. These values were higher than those reported from temperate regions and may be attributed to intrinsic differences between temperate and local forages. Both studies indicated that the greater proportion of effective grazing was accomplished during daylight hours. However, under both systems of management there appeared to be a major consumption peak of about one hour's duration, during the night. It seems essential, on the basis of these observations, that exotic dairy cattle in the mid-country of Sri Lanka be given maximum daytime on pasture. If zero grazed, grass should be offered at least in three feeds, corresponding to the major periods of consumption. Since about 30% of the grazing or zero grazing occurred between 6.00 p.m. and 6.00 a.m., it is also suggested that cattle be enclosed at night where they could do a reasonable amount of grazing or be provided with adequate cut fodder at night in order to ensure maximum production.

1. Introduction

Adequate information is available on the grazing behaviour of cattle in the temperate regions. However, only few such studies have been made under tropical conditions specially with temperate breeds of cattle.

Evidence from literature indicate that in warm weather animals graze at night for long periods. Wallace and Kennedy[16] reported that night grazing accounted for 40% of total grazing time of beef cattle during the summer months in New York State. Day temperatures of 80°F to 95°F in Louisiana resulted in a complete reversal of temperate climatic pattern of grazing ; over 70% of the total grazing time of 7.2 hours being done at night.[14] Even with day temperatures in the range of 72°F to 82°F, Friesian cows in Fiji did 67% of their grazing at night,[13] suggesting that the grazing habits of cattle in the tropics were radically different from those in temperate zones.

In Sri Lanka, only a few studies of this nature have been undertaken. At the Coconut Research Institute, Gunasekera[6] made observations on the time spent in grazing by indigenous Sinhala Cattle tethered to coconut palms. He observed that on an average these cows grazed 10.3 hours and that the bulk of the grazing occurred during the hottest part of the day. At the Dry Zone Agricultural Research Station, Fernando and Sivalingam[3,4] made two studies on the grazing habits of Zebu cattle. They found that Sahiwal heifers grazed mostly during daylight hours, while the nights were mainly devoted to rest. They suggested that the condition of the pasture was a major factor which influenced grazing habits of cattle.

Several investigations have been reported where behavioural studies have been successfully used in solving grazing management problems. Hughes and Harker[10] showed how behavioural studies can be used to improve animal weighing methods, when cattle are at grazing. In Sri Lanka, there is little information available on the precise management practices that should be adopted in order to gain the maximum benefit from our established pasture. At a time such as this when a tremendous emphasis is being placed on dairy farming, specially in the mid-country of Sri Lanka where diversification of marginal tea lands are being considered, it would be most appropriate to gather precise information on grazing habits of cattle, in order that maximum benefit can be achieved from grassland management.

The main objective of the present investigation was therefore to gain knowledge on the grazing habits of three exotic dairy breeds (Holstein-Friesian, Ayrshire and Jersey) in the mid-country of Sri Lanka and to make tentative recommendations for maximizing yields through improved grazing management practices. The investigations which included a barn study (zero-grazed) and a field study (free-grazed) was conducted at the Experimental Dairy Unit of the Department of Animal Husbandry, University of Sri Lanka, Peradeniya Campus.

2. Experimental

Two studies were undertaken :

(*a*) Study I — A barn study where zero-grazing was practised.

(*b*) Study II — A field study where free-grazing was practised.

2.1. Animals

Both studies were undertaken with six milking cows from the exotic breeds (2 of each) Friesian, Ayrshire and Jersey. They were familiar to being handled both in the barn and in the field without causing any disturbance.

2.2. Herbage

For Study I, animals were given *ad libitum* good quality Pusa Giant Napier fodder in feed troughs in weighed quantities of 18 to 20 kg. Feed refusals by individual animals were recorded every 24 hours.

Study II was conducted in a 1 acre paddock of *Brachiaria brizantha* (Hoscher) stapf. fertilized with urea at the rate of 336 kg nitrogen per hectare per year, one month prior to the commencement of the experiment.

2.3. Weather

Since both trials fell within the Maha Season (North-East Monsoon), climatic conditions were much similar, except for the slightly heavier rain during the barn study.

A record of hourly meteorological data are given in Appendix Table I. Rainfall data for the 48 hour period were obtained from the Central Agricultural Research Institute, Peradeniya, located about 16 km from the experimental site.

2.4. Housing

Study I—Animals were housed in a half brick-walled, asbestos roofed and well ventilated barn having a row of tie points on either side of a middle passage. Animals were kept tied with chains which were well adjusted to allow comfortable movement.

Study II—The 0.4 ha paddock (70 yds × 70 yds) in which the animals grazed during the field study, had a tree by the fence on one side which provided shade to the animals. A shed constructed at the centre of the paddock was used for making observations.

2.5. Milking

During both studies animals were milked by hand at the milking parlour located in the barn, which was about 450 m away from the paddock used for Study II. Milking was done at 6.00 a.m. and 2.00 p.m.

2.6. Water and feed supplements

The amounts of concentrates ('Morlac' by B.C.C. Ltd.) given to the cows varied according to the milk yield. During both studies, the appropriate quantity of concentrates were given at the time of milking, in two equal feeds. All cows were provided with adequate mineral mixture which was fed along with the concentrates.

All animals had access to drinking water. The quantity of water consumed by all six animals was measured during both studies.

2.7. Observation techniques

Observations were made for a period of 48 hours in both studies. The activities of each animal were recorded continuously at 5 minute intervals. During Study I, a pressure lamp was used to facilitate observations in the night. In addition to a pressure lamp in the observation shed, a flashlight was also used in the night during the field study.

The activities of the animals were classified into :

1. Grazing or zero-grazing—time spent consuming pasture grass in the field or cut herbage in the barn.
2. Concentrate feeding—time spent eating concentrates.
3. Ruminating—time spent ruminating, both while standing and lying down.
4. Idling—time spent without any activity, both while standing and lying down.
5. Milking—time spent on milking. (Time spent waiting at the gathering yard during Study I and time spent in walking to and from the milking parlour during Study II, were also included under this activity.)

During both studies, the frequency of defaecations and urinations, and the total weight of dung voided by three labelled animals in Study I and one labelled animal in Study II, were also recorded.

The distance walked by one particular animal during the 48 hour period in Study II was measured using the technique of Hancock.[7]

The total quantity of water used for bathing cows and washing the barn was also measured.

A sample taken from herbage and concentrate offered and the faeces voided, were analysed for dry matter, ash, crude protein, crude fibre and calcium by conventional methods.

3. Results

The mean chemical composition of feed and faeces for both studies is given in Table I.

3.1. Behaviour Observations

The time spent in various activities by cattle during the 48 hour period for both barn and field studies is presented in Table 2. In the barn, animals spent an average of 8.80 hours/day (range 7.78 h to 9.92h) zero-grazing, while in the field the average time occupied in grazing was 9.55 h/day (range 8.33 h to 10.83h). There was a

marked difference between the ruminating time in the field (7.12 h/day) and the ruminating time in the barn (6.00 h/day). Animals were found to idle more when in the barn than when in the field. However, the total time spent lying down was similar under both conditions (Table 2).

TABLE 1. Average Chemical Composition of feed and faeces

	Dry matter %	Crude protein	Crude fibre	Ash	Calcium
		(% in dry matter)			
STUDY I					
Fodder	17.83	15.37	29.07	12.29	—
Concentrate	89.63	21.77	—	—	—
Faeces	16.12	9.88	—	—	0.879
STUDY II					
Grass (at commencement of experiment)	17.90	13.63	22.16	12.27	—
Grass (at the end of experiment)	18.16	10.74	24.92	11.86	—
Faeces	14.46	7.28	—	20.83	1.32

TABLE 2. Time spent per animal in various activities (minutes)

Activity	Barn Study			Field Study		
	Day 1	Day 2	Mean	Day 1	Day 2	Mean
Grazing or zero grazing	537	519	528	559	587	573
Concentrate feeding	2	3	2	—	—	—
Ruminating	315	404	360	428	426	427
Idling	514	403	459	283	272	277
Milking	72	111	91	170	155	163
TOTAL	1440	1440	1440	1440	1440	1440
Times spent lying down	98	439	537	74	429	503
Ratio of grazing/ruminating (G/R)	1.7048	1.2847	1.4667	1.3061	1.3779	1.3419
Number of dungings	17.5	16.0	16.8	6.3	9.8	8.1
Number of urinations	20.3	23.2	22.0	5.0	17.2	6.1
Quantity of fresh faeces voided (kg)	19.7	18.8	19.3	7.3	8.2	7.7
Quantity of faeces voided/defaecation (kg)	1.03	1.20	1.11	1.21	1.02	1.10
Distance walked (metres)	—	—	—	1897	1586	1741

The average time spent per animal in various activities during day and night is shown in Table 3. Since it was difficult to observe the exact time of sunrise and sunset during both studies because of the cloudy weather, time of sunrise and sunset were arbitrarily fixed at 6.00 a.m. and 6.00 p.m. respectively.

TABLE 3. Average time spent per animal in various activities during day and night (minutes).

Activity	Barn Study		Field Study	
	Day	Night	Day	Night
Grazing or zero grazing	389	139	357	216
Ruminating	67	293	146	281
Idling	171	288	54	223
Time spent lying down	98	439	74	429
Ratio of grazing/ruminating (G/R)	5.8050	0.4744	2.4452	0.7687
Number of dungings	9.2	7.6	5.6	2.5
Number of urinations	13.6	8.4	3.5	2.6
Quantity of fresh faeces voided (kg)	0.98	9.53	5.44	2.27
Quantity of faeces voided/ defaecation (kg)	1.10	1.12	1.21	0.91
Distance walked (metres)	—	—	1139	602

On this basis under both systems of management over 60% of the total grazing was during the day. Night grazing ranged between 30% to 40%. On the contrary, animals spent more time ruminating during the night ; 81% and 66% of the total ruminating time for barn and field study respectively, was during the night. However, the total time spent on rumination was comparatively higher under free-grazing than under zero-grazing conditions. The pattern and the time spent lying down, both during day and night, appeared to be similar under the two systems of management (Figure 1).

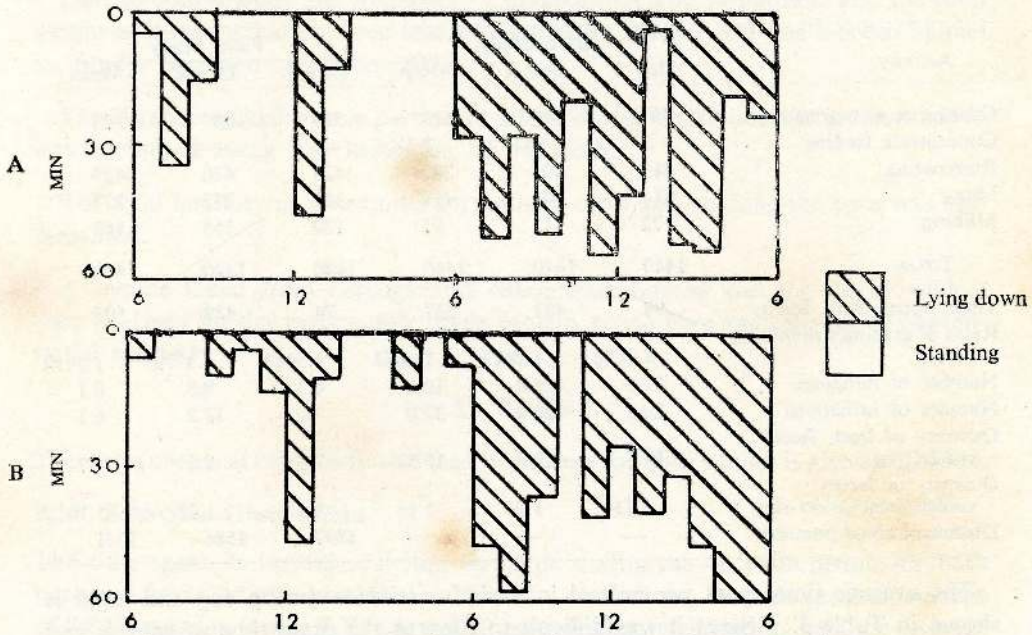

Figure 1. The pattern and time spent lying down during day and night.
A. Barn Study. B. Field Study.

The pattern of zero-grazing and free-grazing habits are shown in Figure 2. There were three major periods of consumption of grass for both barn and field study. Although the forage consumption pattern during the day was similar under both conditions, it differed during the night. The peak night grazing when in the field was around 10.00 p.m., while in the barn this appeared to be around 1.00 a.m.

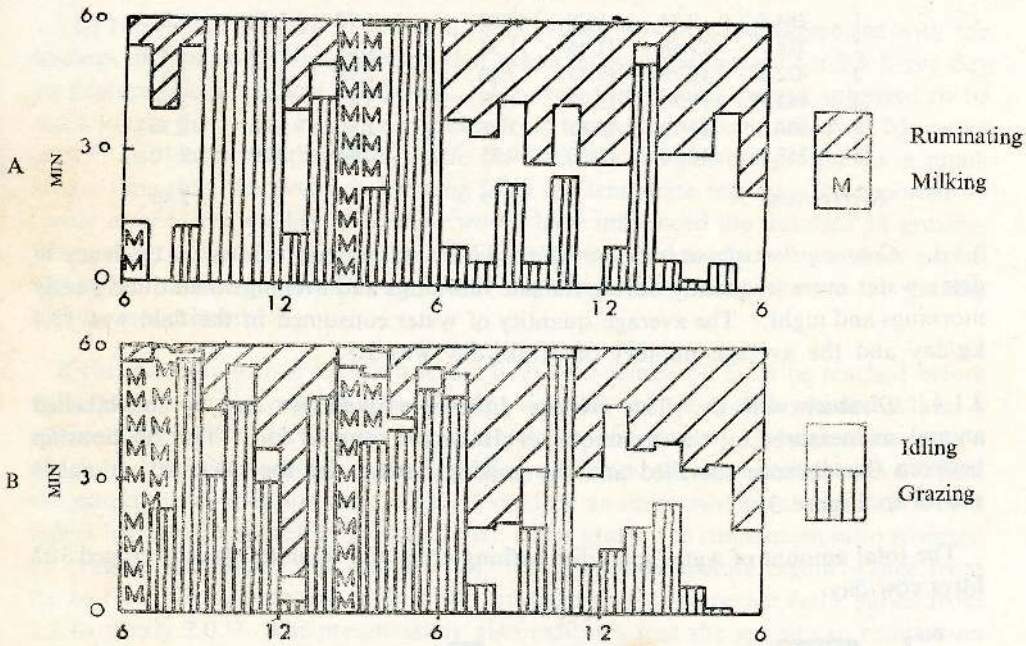

Figure 2. Periodicity of grazing habits under the two systems of management.

A. Barn Study.
B. Field Study.

Although there was a significant difference between individuals in the time spent grazing, ruminating and idling, no breed differences were observed in these activities.

3.1.1. *Elimination behaviour :* The number of defaecations/cow per day appeared to be more under zero-grazing conditions (16.8) than under free-grazing (8.1) conditions. The amount of fresh faeces voided per animal per day under zero-grazing was 19.3 kg compared to 7.7 kg under free-grazing. However, the average weight of faeces voided at each dunging was similar under both conditions (Table 2).

3.1.2 *Voluntary intake and rate of intake (R.I.) of herbage dry matter in barn study:* The daily herbage dry matter intake per cow in the barn study was 12.15 kg or 3.2% of the body weight. However, the rate of intake (R.I.) of herbage dry matter appeared to decrease as grazing advanced on to the second day (Table 4).

TABLE 4. Dry matter intake and rate of dry matter intake in barn study

Cow No.	Live Weight (kg)	Intake of herbage D.M. (kg)			Rate of intake (R.I) (kg/100 minutes)		
		1st day	2nd day	Average	1st day	2nd day	Average
1	284.8	9.84	9.39	9.62	1.95	1.69	1.81
2	388.7	11.48	11.16	11.34	2.61	2.12	2.34
3	422.3	14.79	11.57	13.20	2.98	2.18	2.57
4	442.3	14.70	13.97	14.38	3.67	2.91	3.26
5	366.5	13.79	12.61	13.25	2.56	2.06	2.30
6	357.9	10.16	11.20	10.75	2.04	2.16	2.10
Average/cow				12.15			2.40

3.1.3. *Consumption of water in the field study :* All animals showed a tendency to drink water more frequently during the late mornings and evenings than during early mornings and night. The average quantity of water consumed in the field was 15.4 kg/day and the average number of drinks/day was 2.8.

3.1.4. *Distance walked :* The average distance walked per day by the labelled animal, as measured by the technique of Hancock[7] was 1.7 km. The relationship between the distance travelled and the grazing pattern for the observed animal is shown in Figure 3.

The total amount of water spent for bathing cows and washing stalls averaged 182 litres/cow/day.

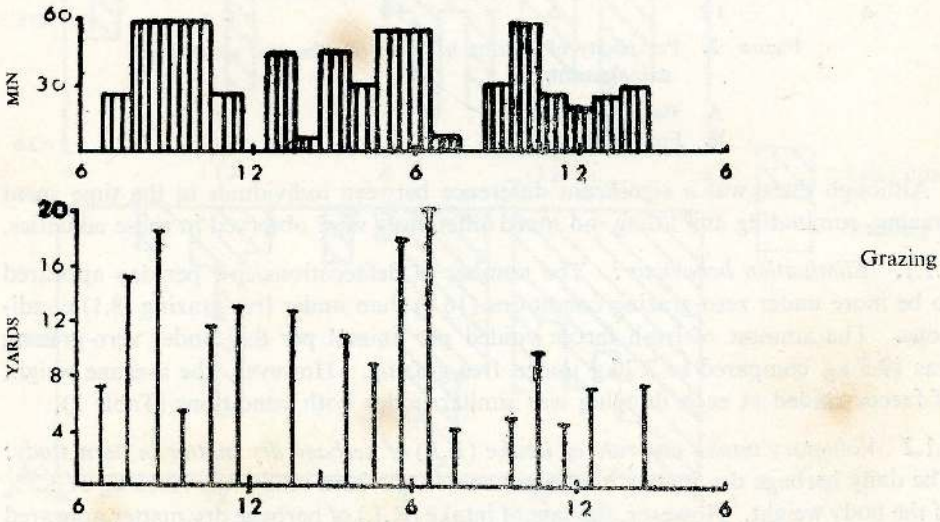

Figure 3. Relationship between distance travelled and grazing pattern in the field study.

4. Discussion

Judging solely from its crude protein content, the pasture consumed in these studies was of relatively good quality (Table 1). Nevertheless, animals exhibited noticeable selectivity while grazing as shown by the longer time spent on grazing.

The time spent grazing in the field (9.55 h/day) was in good agreement with the findings of Goldson,[5] who reported that grade dairy cattle grazed for 9.6 h per day on pasture under tropical conditions. However, this grazing period appeared to be much longer than what available evidence from temperate regions indicates. Mugerwa *et al.*[12] also suggested that dairy cattle on East African pasture grazed for a much longer time than the evidence accruing from the temperate regions. As reported by Castle *et al.*[1,2] the quality of pasture would have influenced the duration of grazing. When on good quality pasture animals have been found to graze for a short period and as the pasture deteriorates in quality and quantity, the duration of grazing activity is increased.[9,15]

If the contention that a certain level of reticulo-rumen fill must be reached before the animals start the process of rumination and that the speed with which this level is attained depends upon among other things, on the rate of herbage consumption which, in turn is influenced by the herbage quality and the degree of selectivity, then the grazing to rumination ratio (G/R) should be an important parameter that would reflect herbage acceptability by the animal. The grazing to rumination ratio reported by Hughes and Reid[11] and Castle *et al.*[1] for cattle in temperate regions range from 0.6 to 1.0. Those observed in East African pastures for temperate cattle varied from 1.2 to nearly 2.0.[12] The present study also indicates that the grazing to rumination ratio for temperate cattle in the mid-country of Sri Lanka is similar to that of temperate cattle in East African pastures. The ratio of 1.47 for a zero-grazing system and 1.34 for a free-grazing system therefore reflects the intrinsic differences between temperate and local forages.

Total rumination time is closely associated with the total food intake.[8] Therefore, a higher grazing to rumination ratio in the barn study would suggest a low pasture dry matter intake by the animals. However, the dry matter consumption by the animals in the barn study was according to expectations. It is, therefore, possible that the grazing animals had a higher dry matter intake than those in the barn.

There was a significant difference in grazing activity between individual cows in the field study. However, no significant difference was found in the zero-grazing activity among cows in the barn study. All animals zero-grazed simultaneously for 6.29 h (71.8% of the total zero-grazing time), while in the pasture, simultaneous grazing occurred only for 4.04 h (42.3% of the total grazing time), suggesting a greater tendency for group activity when housed in a barn.

As a result of less time being spent on grazing, rumination and milking, animals in the barn showed more idling time than those in the field. This coupled with the higher lying down time indicate that the animals in the barn were able to obtain their feed requirements with a smaller expenditure of energy in comparison to those grazing in the field. Thus, the zero-grazing system of management can be considered a more efficient method of obtaining maximum benefit out of the pasture.

There appeared to be highly significant correlations between voluntary dry matter intake and body weight and rate of dry matter intake and body weight ($P = 0.05$), suggesting that both rate of intake and voluntary intake of dry matter are closely related to body weight (Figure 4).

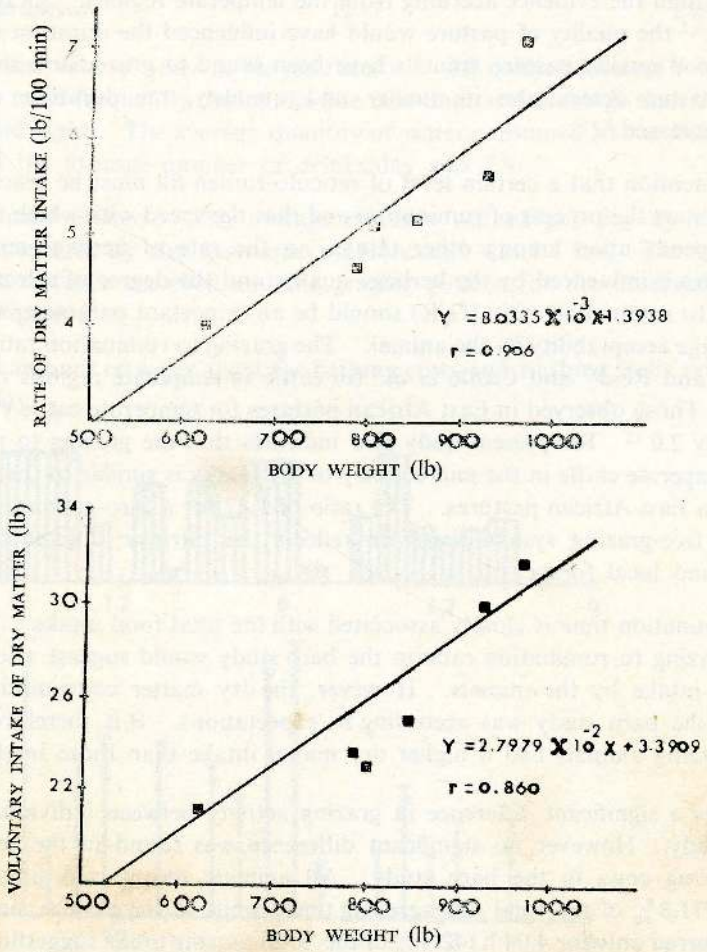

Figure 4. Relationship between rate of dry matter intake and body weight and voluntary dry matter intake and body weight.

The distance walked by a cow during 24 h period appeared to be about half of that reported by Hancock[7] and Castle.[1] As suggested by Hancock[7] it is rather difficult to interpret the factors that may influence walking because of their very number and diversity. However, it is known that grass of poor palatability increases the distance walked by animals. When interpreted this way, it appears that the pasture, animals had access to, was of a high quality. This could also be substantiated by the relatively high crude protein and the low crude fibre content of the *Brachiaria* pasture that was grazed.

The general pattern of activities of dairy cattle at pasture as observed in the mid-country of Sri Lanka seems to be similar to those of temperate areas. However, the absolute duration of grazing was much more protracted than in the temperate region. In the present study, the exotic dairy cattle grazed 537 minutes (39.8%) out of 24 hours.

The observation regarding day and night activities made in these studies are in agreement with studies of similar nature carried out in many tropical climates. Both studies indicated that the greater proportion of effective grazing is accomplished during daylight hours. The figures varying between 60% to 70% reported here are comparable with those of Goldson's [5] 67% and Mugerwa's [12] 60% for grade dairy cattle in Africa. In contrast to the daytime grazing habit, animals under both conditions of management spent most of the night ruminating, suggesting that day-time grazing caused a sufficient rumen-fill to initiate the process of rumination.

In conclusion, it can be tentatively suggested that dairy management systems and practices in the mid-country of Sri Lanka must ensure that animals are allowed the maximum possible time to free-graze or zero-graze during daylight hours, especially when herbage is of marginal quality. But from the point of view of attaining maximum dry matter intake it is also important to provide sufficient feed or allow animals to graze for a short period (about one hour) during the night since there appears to be at least one peak of grazing during the night for both barn as well as field systems of management.

On the basis of these observations, it seems essential that morning milking be accomplished as early as possible and afternoon milking be completed within the shortest possible time, so as to allow the animals maximum possible daylength for grazing or zero-grazing.

Acknowledgements

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Appendix Table 1—Weather Data

Barn Study			Field Study		
Time (h)	Dry bulb Temperature °C	Relative Humidity %	Time (h)	Dry bulb Temperature °C	Relative Humidity %
6.00 a.m.	21.5	89	6.00 a.m.	20.8	94
7.00	22.0	95	7.00	21.5	90
8.00	22.8	92	8.00	21.8	89
9.00	24.0	81	9.00	20.8	88
10.00	26.5	70	10.00	21.5	86
11.00	27.0	63	11.00	21.8	85
12.00	27.5	63	12.00	21.4	89
1.00	27.5	63	1.00	20.9	89
2.00	27.0	66	2.00	20.9	89
3.00	27.5	63	3.00	21.0	87
4.00	28.0	63	4.00	20.7	86
5.00	25.0	77	5.00	20.5	88
6.00 p.m.	24.0	81	6.00 p.m.	20.2	88
7.00	24.0	81	7.00	20.0	90
8.00	23.0	85	8.00	20.1	87
9.00	23.0	85	9.00	20.4	83
10.00	23.0	85	10.00	20.4	88
11.00	22.5	85	11.00	20.4	86
12.00	22.5	90	12.00	20.4	85
1.00	21.5	93	1.00	20.3	87
2.00	21.5	93	2.00	20.3	89
3.00	21.8	97	3.00	20.3	92
4.00	21.8	85	4.00	20.5	89
5.00	21.5	88	5.00	19.8	94
6.00 a.m.	21.5	88	6.00 a.m.	19.8	94
Rainfall—80.4 mm/48 h			Rainfall—43.6 mm/48 h		

References

1. Castle, M. E., Foot, A. S. & Halley, R. J. (1950). *J. Dairy Res.* **17** : 215.
2. Castle, M. E. & Halley, R. J. (1953). *Br. J. Anim. Behav.* **1** : 139.
3. Fernando, G. W. E. & Sivalingam, T. (1961). *Trop. Agric.* **117** : 89.
4. Fernando, G. W. E. & Sivalingam, T. (1963). Unpublished data.
5. Goldson, J. R. (1963). *E. Afr. Agric. For. J.* 29(1) : 72.
6. Gunasekera, G. C. M. (1958). *Ceylon Cocon. Q.* 9(1-2) : 4.
7. Hancock, J. (1950). *N.Z.J. Sci. Technol.* **32** (4) : 22.
8. Hancock, J. (1958). *J. agric. Sci.* **50** (3) : 284.
9. Harker, K. W. Rollinson, D. H. L., Taylor, J. I., Gourlay, R. N. & Nunn, W. R. (1961). *J. agric. Sci.* **56** : 137.
10. Hughes, G. P. & Harker, K. W. (1951). *J. agric. Sci.* **40** : 403.
11. Hughes, G. P. & Reid, D. (1951). *J. agric. Sci.* **41** : 350.
12. Mugerwa, J. S., Chistensen, D. A. & Ochetim, S. (1973). *E. Afr. agric. For. J.* **39** (1) : 1.
13. Payne, W. J., Lairy, W. I. & Raivoka, E. N. (1951). *Nature* (Lond.) **167** : 610.
14. Seath, D. M. & Miller, G. D. (1946). *J. Dairy Sci.* **29** (4) : 119.
15. Smith, C. A. (1959). *J. agric. Sci.*, **52** : 369.
16. Wallace, J. D. B. & Kennady, W. K. (1944). *J. agric., Sci.* **34** (4) : 190.

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A Preliminary Study on Processing of Cashew-nuts and Production of Cashew-nut Shell Liquid (CNSL) on a Commercial Scale in Sri Lanka

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Abstract : At present processing of cashew-nuts in Sri Lanka is done at a cottage level using traditional methods. The quality of the kernels so produced shows considerable variations in degree of "completeness" and colour. Further, the liquid present in the cashew shells which consists of phenols and known commercially as a versatile industrial raw material, is not recovered. Production of cashew-nuts in Sri Lanka is expected to show a five-fold increase within the next few years. Therefore, a study has been undertaken to investigate processing of cashew-nuts and production of cashew-nut shell liquid on a commercial scale in Sri Lanka. It has been established that using the "hot-oil-bath" method, cashew-nuts can be processed satisfactorily and cashew-nut shell liquid can be recovered efficiently with 185°C to 190°C as the temperature of processing. The time of processing can be either 1½ minutes or 4 minutes.

1. Introduction

The cashew-nut is 2 to 4 cm long and kidney shaped. The shell of the nut is about 0.3 cm thick, having a soft leathery outer skin and a thin hard inner skin. Between these skins is a soft honeycomb structure containing a viscous reddish-brown liquid known as Cashew-Nut Shell Liquid (CNSL). It is a phenolic material having an irritating action on the human skin and gives natural protection against insects for the white cashew kernel. The shell forms about 60% to 70% of the raw cashew-nut and CNSL is present to the extent of about 25% to 30% in the shell. CNSL is a versatile industrial raw material with a wide range of useful commercial applications.

At present, Sri Lanka produces about 100 tons of cashew-nuts. This production is expected to show a five-fold increase within the next few years. Hence it is of extreme importance to initiate studies on the processing of nuts and production of CNSL on a commercial scale. In this paper we report results of a laboratory scale investigation on the commercial processing of cashew-nuts.

2. Processing of Cashew-Nuts

2.1. Present Method of Processing of Cashew-Nuts in Sri Lanka.

In Sri Lanka, the extraction of the kernel from the shell of the cashew-nut is a manual operation. The sun-dried or roasted nuts are cracked with a small hammer to split the shell along the natural line of cleavage. The kernel is then carefully removed and slightly roasted to remove the testa and also to improve the taste. All these operations are carried out traditionally by the women-folk.

This method, although satisfactory at the cottage level, cannot be applied to produce cashew kernels on a commercial basis. The quality of the kernels in respect of the degree of "completeness" and colour shows considerable variations. Also, when the nuts are roasted to make the shell brittle, CNSL is partly destroyed and the remaining liquid undergoes certain chemical changes (polymerization).

2.2. The "Hot-Oil-Bath" Method

The "hot-oil-bath" method is the most common commercial way of processing the nuts and extracting CNSL partially. Here the raw nuts are roasted in a bath of CNSL maintained at 185°C to 190°C, the time of contact of the nuts with the liquid being a few minutes. The shell of the nut gets brittle due to partial release of CNSL into the liquid bath. The temperature of the bath should be maintained at 185°C to 190°C. If it is below this range, the process tends to be inefficient and at higher temperatures considerable damage to the liquid and to the kernel takes place. The nuts so processed are wiped off of any CNSL adhering to the surface using sawdust or ashes and then cracked using a small hammer to extract the kernel. The quality of the kernels depends much on observing the proper temperature of the CNSL bath (185°C to 190°C), optimum time of contact of the nuts with the liquid and on the skill of labour cracking the nuts.

3. An Experimental Study of the "Hot-Oil-Bath" Method

3.1. Experimental Procedure

Experiments on the "hot-oil-bath" method were carried out using facilities available on the cashew plantation of the Cashew Corporation at Kondachchi in the Mannar District. Processing of the raw nuts was affected by dipping the nuts placed in a wire basket in a hot CNSL bath. The CNSL bath consists of a mild steel rectangular tank, which is heated using firewood. The liquid was stirred well during the operation to ensure uniform heating and the temperature was recorded by means of a thermometer immersing deep into the liquid through an opening on a side-wall of the tank. The heating was so manipulated to maintain the temperature of the bath between 185°C to 190°C. The time of retention of the nuts in the liquid was varied between

1½ minutes and 9 minutes. After each operation, the CNSL adhering to the basket and the nuts was allowed to drain off into the main bath and then the nuts were tumbled in ash to absorb the remaining liquid coating the outside of the shell. The nuts were then cracked with a small hammer to extract the kernel.

3.2. Extraction of the residual CNSL

During processing of the nuts in the "hot-oil-bath" a portion of CNSL is released into the liquid bath. To extract the residual CNSL in the shells, after the kernel has been removed from the processed nuts, the shells were subjected to a mechanical extraction process. A hand operated screw-type expeller available at the Ceylon Institute of Scientific and Industrial Research was used for this purpose. CNSL thus obtained was filtered through a filter cloth to remove any solid matter and the shell-residue was extracted with n-hexane to recover any residual liquid. The CNSL content of the shells of the nuts processed at different retention times in the hot-oil-bath was calculated and these CNSL samples were analysed, according to the Indian Standards Specification for CNSL ; IS : 840—1964. CNSL content of the raw (unprocessed) nuts was also determined, thus the amount of liquid extracted during processing of the raw nuts could be calculated. The cashew kernels from the nuts processed for different time intervals were examined for physical appearance and taste.

3.3. Changes in the properties of CNSL on prolonged heating at 185°C to 190°C

It is well known that CNSL when heated to high temperatures undergoes certain chemical changes, for example, polymerization. During the processing of cashew-nuts in the hot-oil-bath, CNSL in the bath as well as the liquid that gets continuously extracted into the bath are subjected to prolonged heating at 185°C to 190°C. For the process to be economically feasible, the quality of CNSL in the bath should not deteriorate below the accepted standard specifications, for otherwise it will not be possible to market the liquid. Therefore proper consideration must be given to any changes undergone by CNSL in the oil-bath during processing and a study was undertaken to follow the changes in physical properties of a sample of CNSL on prolonged heating at 185°C to 190°C. The sample was heated for three days, for a period of six hours a day and the viscosity, iodine value and specific gravity were determined after each day of heating.

3.4. Results and observations

The results and observations of the experiments to process raw cashew-nuts in a hot bath of CNSL are tabulated in Table 1.

TABLE 1. Properties of the CNSL and Cashew Kernel Obtained by Different Extraction Procedures

Sample	% CNSL content of the shells			Fraction of CNSL extracted during hot-oil-bath process %	Iodine value of CNSL (Catalytic method)	Specific gravity of CNSL 30°C	Viscosity of CNSL in CP at 30°C	Physical appearance and taste of the kernel
	Extracted on expelling %	Extracted on solvent extraction of the residue after expelling %	Total CNSL %					
Raw nuts	23.5	1.5	25	—	423.0	0.9495	93.49	White/acrid taste
Processed at 185°C to 190°C for 1½ minutes	20.0	3.0	23	8	418.0	0.9500	105.63	White/acrid taste
Processed at 185°C to 190°C for 3 minutes	10	12	22	12	416.4	0.9542	114.51	White/bland taste with a slight acrid taste
Processed at 185°C to 190°C for 4 minutes	5	10	15	40	416.5	0.9520	120.20	White/pleasant bland taste
Processed at 185°C to 190°C for 6 minutes	1	11	12	52	420.65	0.9534	134.32	Pale brown/slight roasted taste
Processed at 185°C to 190°C for 9 minutes	0	10	10	60	420.7	0.9554	158.82	Scorched/over roasted taste
CNSL from the processing bath	—	—	—	—	381.3	0.9664	809.3	—

Table 2 contains the results of an experiment to study the variations in the physical properties of a sample of CNSL on prolonged heating at 185°C to 190°C.

TABLE 2. Changes in the Physical Properties of a Sample of CNSL on Prolonged Heating at 185°C to 190°C

No. of hours at 185°C to 190°C	Iodine value	Specific gravity at 30°C	Viscosity in CP at 30°C
0	392.5	0.9656	180.8
6	378.4	0.9636	229.5
12	375.3	0.9670	397.1
18	380.1	0.9734	681.6

4. Discussion

It is evident from the results that CNSL from the shells of the nuts processed for different intervals of time all satisfy the Indian Standard Specifications in respect of iodine value (375), specific gravity (0.950 to 0.970 at 30°C) and viscosity (550 CP, max.). Optimum colour and taste of the kernel can be achieved by processing for 3 to 4 minutes at 185°C to 190°C. When the nuts are processed for 3 minutes about 12% of the total CNSL gets extracted and when the processing time is 4 minutes about 40% goes into the extraction bath.

After 3 minutes extraction in the hot-oil-bath, a further 45% of CNSL can be extracted by subjecting the shells after decortication to mechanical expelling. The solvent extraction process to recover the residual liquid is too expensive and is commercially not viable. This means that only about 57% of the total CNSL is extractable by combining the hot-oil-bath extraction with subsequent expelling of the decorticated shells. Similarly, about 73% of the total CNSL can be extracted when the raw nuts are processed for 4 minutes in the hot-oil-bath followed by expelling the shells. From the nuts that are processed for only $1\frac{1}{2}$ minutes, about 80% of the liquid can be extracted alone on expelling the shells. But the taste of kernels thus obtained is unsatisfactory. The acrid taste can however be easily eliminated by a post-roasting operation.

The results of the experiments outlined so far show that for optimum recovery of CNSL and for good quality kernels, the following processing times and temperatures are feasible :

(*a*) at 185°C to 190°C for $1\frac{1}{2}$ minutes followed by roasting the extracted kernels for a short period of time to improve the taste,

(*b*) at 185°C to 190°C for 4 minutes.

In the case of (*b*) of the 73% commercially extractable CNSL (not taking into consideration the amount of solvent extracted CNSL) about 64% gets extracted in the hot-oil-bath.

It can be seen from Table 2 that when a sample of CNSL is heated for 18 hours at 185°C to 190°C the values for viscosity and the specific gravity fail to satisfy the Indian Standard Specification for CNSL. In this study, heating was not done continuously for 18 hours but for periods of 6 hours a day for three days, a more realistic condition in the commercial operation of the process.

This study indicates that the quality of CNSL in the processing bath after three days (assuming a daily extraction period of six hours) will be below the accepted specifications. Therefore if the liquid in the processing bath is used for three days or more, then it will not be possible to market the CNSL as good quality oil. Since the economy of the process depends both on the quality of the cashew kernels and on the quality of CNSL produced it will be important to replace the liquid in the bath with fresh liquid after two days of operation. After twelve hours at 185°C to 190°C, which is equivalent to two days of commercial processing with an extraction period of six hours a day, the quality of the liquid satisfies the Indian Standard Specifications. Analysis of a sample of CNSL from the processing oil-bath at Kondachchi gave a very high value for viscosity (Table 1) indicating that the liquid has been used for a long period of time.

4.1. A comparison between extraction of the raw nuts for 1½ minutes and for 4 minutes

From Table 1 it is seen that when the nuts are processed for 1½ minutes at 185°C to 190°C, the amount of CNSL expelled into the oil-bath is about 8% and when they are processed for 4 minutes 40% of the total available CNSL is extracted. Also, while 80% of the liquid can be extracted by expelling the shells after the hot-oil-bath extraction for 1½ minutes, only about 20% can be extracted the same way from the shells after a 4 minutes extraction in the oil-bath. Thus renewal of CNSL in the oil-bath after two continuous days processing will be an essential requirement in the 4 minute process. This means for successful operation of the plant on every third day of operation there should be a fresh supply of CNSL from the expeller process which is at least enough to fill the processing bath upto the minimum operational level.

If the raw nuts are to be processed only for 1½ minutes, then since a major portion (80%) of CNSL can be recovered by the expeller process, renewal of the liquid after 2 days of operation will not pose any problems. Even if the bath liquid is not replaced and is used for a longer period of time (much more than two days) it will not be economically very critical because of the 80% good quality CNSL recoverable from the expeller process.

5. Conclusion

A laboratory scale study has been done on the processing of cashew-nuts and production of cashew-nut shell liquid on a commercial basis. It has been established that the raw nuts can be processed in a hot bath of CNSL either (*a*) at 185°C to 190°C for 1½ minutes followed by roasting of the kernels extracted to improve the flavour, or (*b*) at 185°C to 190°C for 4 minutes, no further treatment of the kernels being necessary.

In the case of (*a*) about 80% of the total CNSL can be extracted by expelling the shells of the processed nuts and in the case of (*b*) about 40% of CNSL being extracted into the hot-oil-bath during the processing of the nuts. Renewal of the liquid in the processing bath every three days is to be affected, this being essential if the nuts are to be processed for 4 minutes.

Which of the conditions of operation outlined above is suitable will depend on the cost of further processing of the kernels after the hot-oil-bath treatment in the case of 1½ minutes extraction and heating the CNSL bath for an extra 2½ minutes in the case of the 4 minutes extraction. This cost comparison study has to be done at least on a pilot plant scale.

For the domestic market the traditional processing methods adopted by small holders to extract the cashew kernels appear to be satisfactory. The cashew-nut shells from sun-dried and decorticated nuts can be expelled using a screw type expeller to yield good quality CNSL (Table 3). The present availablity of CNSL assuming that all the shells from the processed nuts could be collected and expelled is about 125,000 kg of the liquid. Central processing factories will be an essential feature of the Cashew Industry in Sri Lanka in the very near future when the cashew cultivation of about 25,000 acres on a plantation basis goes into full production. A situation where the cashew-nuts produced by the small holders will be for local consumption and that produced on state or private plantations for export market can well be anticipated. Cashew-nut shells from the smallholders as well as from the plantations could be subjected to central processing (expelling) to obtain CNSL which can partly be used locally and partly exported. At present, export prospects for cashew kernels and CNSL are promising.

TABLE 3. Analysis of a Sample of CNSL obtained by Expelling shells from Sun-Dried and Decorticated Cashew-Nuts

Property	Sample	Specification
(1) Specific gravity at 25°C	0.9650	0.950 — 0.965
(2) Viscosity at 25°C	1.60	1.5 — 3.5
(3) Volatile loss at 105°C	0.21	1% max.
(4) Iodine value at 25°C	307.4	250 min.
(5) Ash%	1.50	1% max.
(6) Distillation test (3.00 mm/Hg)		
Initial pt. (0°C)	135.0	190°C min.
Distillate below 205°C	2.7	3.0% max.
Total distillate	75.0	60.0% max.

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References

1. ABEYSINGHE, A. (1976). *Export prospects for Cashew, Indian Cashew Journal*, **10** (4) : 9-13.
2. PARRY, C. E. (1968/1969). *Marketing of cashew-nuts—Factors promoting growth and change.* Study commissioned by the Latin American Agricultural Marketing Institute, Bogota, Colombia.
3. RAJAPAKSE, R. A. (1976). *Cashew-nut-shell liquid, Exponews* (Sri Lanka), **1**(6) : 13-17.
4. RUSSELL, D. C. (1969). *Cashew-nut processing* Agricultural Services Bulletin No. 6, Rome—Food and Agriculture Organisation of the United Nations.
5. WILSON, R. J. (1975). *The market for cashew-nut kernels and cashew-nut shell liquid.* Report G 91, London. Tropical Products Institute.

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Radiosensitivity of Winged Bean and Passion Fruit Seeds on Gamma Irradiation

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Abstract : Seeds of winged bean and passion fruit irradiated with gamma rays at dosages ranging from 10 Kr to 70 Kr and 15 Kr to 25 Kr respectively were germinated in flats in a plant house. Winged bean which had a LD_{50} at 30 Kr to 40 Kr was more tolerant to gamma irradiations when compared to passion fruit which had a LD_{50} at 17.5 Kr to 20 Kr. Irradiations above 40 Kr and 20 Kr were detrimental to winged bean and passion fruit respectively. All the seedlings of winged bean that germinated survived, but in passion fruit there was seedling mortality which increased with irradiation dosage.

1. Introduction

Winged bean *Psophocarpus tetragonolobus* (L) DC and passion fruit *Passiflora edulis* Sims var. *flavicarpa* are two promising tropical horticultural crops of the vegetable and fruit groups respectively, which have a potential for commercial expansion in Sri Lanka. All known cultivars and strains of winged bean are climbing forms that require staking or trellissing, two practices which increase the cost of materials and labour. Flowering being acropetal, they give rise to fruits which mature at different times, resulting in a staggered harvest. While these characteristics would be advantageous in subsistence farming and home garden vegetable culture in developing countries, they are disadvantageous for large-scale commercial farming. The need to induce short erect mutants that could be used to breed short age cultivars which would flower and develop fruits uniformly is therefore evident.

The vigorous vines of passion fruit, also require costly trellissing. Moreover, since the fruit bearing part of a shoot is on the new growth, pruning has to be done periodically to induce new shoot formation in order to ensure continuity of production. While pruning adds to the cost of production, the removal of vegetative growth causes a setback and delays production after the first year. Short internode mutants in passion fruit would enable a grower to increase the density of plants per hectare and also reduce pruning costs without sacrificing the productivity of the plant, thereby increasing the profitability from passion fruit plantings.

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The use of ionising radiations to induce dwarf mutants is well known. A prerequisite for their use is to evaluate radiation sensitivity in order to recognise a suitable dosage range for mutation work which is reported in this paper.

2. Materials and Methods

In winged bean, two irradiation experiments were conducted. In the first study, mixed samples of fresh seeds that were harvested from local cultivated strains were irradiated with 10, 20, 30, 40, 50, 60 and 70 Kr of gamma rays in the Co 60 chamber of the Central Agricultural Research Institute, Peradeniya. A sample of 40 seeds was irradiated at each dosage. When the germination results of the first experiment were known, a second experiment was conducted on seeds of the same batch using a narrower dosage range of 15, 17.5, 20, 22.5, 25, 27.5 and 30 Kr. These seeds were irradiated 25 days after the first one. In both experiments, germination was scored every other day. Seedling height was measured weekly up to 3 weeks in the first experiment.

In passion fruit, freshly extracted seeds of a local selection were air dried in the laboratory at 26°C and 100 seeds each were irradiated 5 days after extraction at 15, 17.5, 20, 22.5 and 25 Kr. Because passion fruit seeds are slow germinators when compared with winged bean their germination was scored weekly.

The irradiated seeds of both species were sown 1 cm deep in wooden flats filled with a mixture of sterilised top soil and sand, at a spacing of 5 cm × 8 cm for winged bean and 5 cm × 2 cm for passion fruit. The flats were maintained in a plant house having diffused sunlight throughout the experimental period. In passion fruit, three classes of seedling vigour were scored on the basis of the time taken to expand the first leaf fully. The flats were watered every morning until germination was completed and once in 2 days thereafter.

3. Results

3.1. Germination

The unirradiated seeds of the first experiment in winged bean had 80% germination. In contrast, seed irradiated with 10 Kr had 92% germination and at 20 and 30 Kr all the seeds germinated (Figure 1). When the dosage was increased to 40 Kr, germination dropped to 50% and still higher dosages were detrimental to the seeds. In the control and all treatments, germination was completed in 9 days. The rate of germination was most rapid in the 10 Kr and 20 Kr treatments and the highest rate was noted during the first day of emergence (Table 1). Germination was slowest in the 40 Kr treatment and its highest rate was recorded on the fifth day after the emergence of the first seedling. In the second experiment where a narrow dosage range was used, germination dropped from a maximum of 70% at 15 Kr to 42% at 30 Kr. A stimulation of germination was however recorded at 25 Kr. Germination in this instance took 15 days to complete. The rate of germination was highest in all treatments between 7 to 13 days after emergence of the first seedling.

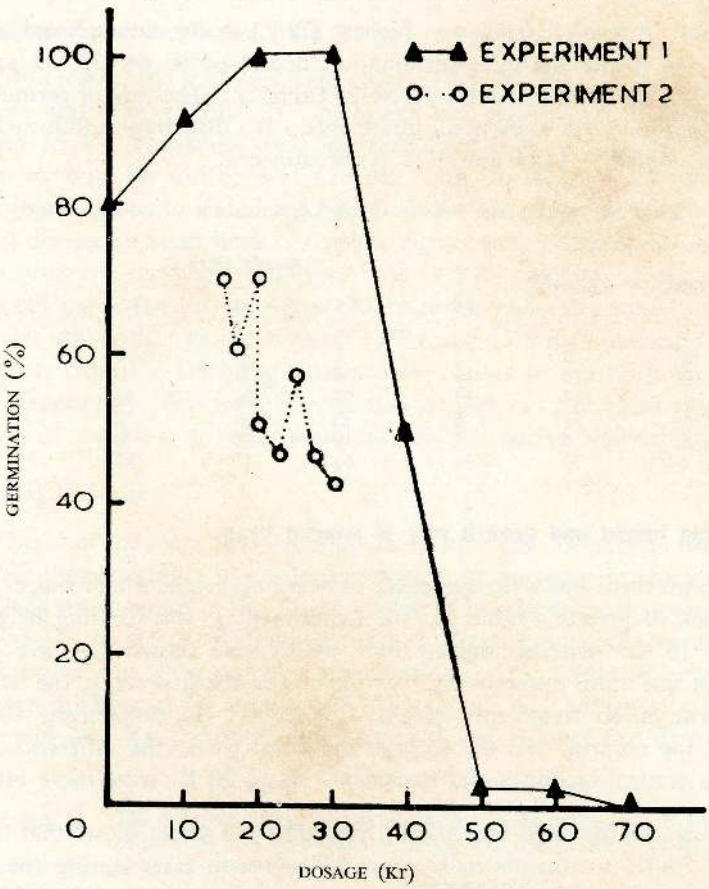

Figure 1. Percentage germination of winged bean seeds at different irradiation dosages.

TABLE 1. Rate of germination of winged bean at two day intervals.

Dosage	Day of germination								Total germinated
	1	3	5	7	9	11	13	15	
EXPERIMENT I									
Control	18	4	8	0	2				32
10 Kr	30	4	2	0	1				37
20 Kr	30	6	2	2	0				40
30 Kr	20	9	8	1	2				40
40 Kr	1	3	9	2	5				20
EXPERIMENT II									
15 Kr	3	3	2	2	6	2	6	4	28
17.5 Kr	0	2	2	10	2	4	2	2	24
20 Kr	3	0	2	3	5	2	3	2	20
22.5 Kr	3	0	1	2	6	3	3	0	18
25 Kr	2	2	2	3	5	6	3	0	23
27.5 Kr	0	2	2	1	4	1	8	0	18
30 Kr	3	2	0	3	2	5	1	1	17

Germination in passion fruit, was highest (79%) in the unirradiated and 15 Kr treatments. At higher dosages, germination decreased to 64, 32, 33 and 20 per cent at 17.5, 20, 22.5 and 25 Kr respectively (Table 2). The rate of germination was highest during the fourth week in all treatments. It's distribution followed a normal curve in the control, 15 Kr and 17.5 Kr treatments.

TABLE 2. Percentage weekly rate of germination of passion fruit

Week	Control	Dosage (Kr)				
		15	17.5	20	22.5	25
2	0	5	1	0	0	0
3	13	11	6	0	0	0
4	63	55	52	26	31	20
5	3	6	5	6	2	0
6	0	2	0	0	0	0
Total (%)	79	79	64	32	33	20

3.2. Seedling height and growth rate in winged bean

In winged bean there was a dosage effect on seedling height which was evident from the first week of growth (Table 3). In Experiment 1, the seedling heights of the control and 10 Kr treatment during the 3 weeks were similar. Above 20 Kr, the dosage effect was more pronounced. At the end of the first week, the height in the 30, 40, 50 and 60 Kr treatments were 6, 3, 2 and 0.1 cm, respectively, compared to 14.5 cm in the control. In the second and third week, the differences in height between the control seedlings and treatments above 20 Kr were more obvious.

The growth rate (cm/day) determined for the first 3 weeks shows that the control, 10 Kr and 20 Kr treatments had comparable growth rates during the first week whereas the rates were lower at higher dosages. During the second and third weeks, the 10 Kr treatment maintained the growth rate of the control but slower growth rates were observed at the higher dosages.

TABLE 3. The effect of increasing dosage on the height and rate of growth of winged bean seedlings during the first three weeks.

Dosage	Height (cm)			Growth rate (cm/day)		
	Week			Week		
	1	2	3	1	2	3
Control	14.5	36	60	2.1	3	3.2
10 Kr	13.5	34	60	1.9	2.9	3.2
20 Kr	13.5	24	46	1.9	2.5	2.7
30 Kr	6	11	28	0.8	0.7	2.3
40 Kr	2	4	13	0.3	0.3	1.3
50 Kr	2	3	4	0.3	0.1	0.1
60 Kr	0.1	1	2	—	0.1	0.1

3.3. Seedling vigour in passion fruit

During early growth, the seedlings were grouped visually into three classes, vigorous, intermediate and slow (Figure 2). Although the germination percentages of the control and 15 Kr treatments were identical (Table 2), the former had a larger proportion of vigorous seedlings at 6 weeks. By the eighth week, all the control seedlings were vigorous. At 17.5 Kr and above, the proportion of slow growers was highest during the sixth week. From the eighth week, the proportion of vigorous seedlings among the surviving seedlings of the 17.5 Kr seedlings increased but at the two highest dosages the proportion of intermediate and slow seedlings among the survivors was still high. In the control, 15 Kr and 17.5 Kr treatments there was a shift of plants from the slow and intermediate classes to the vigorous class as the seedlings became older. This was not evident in the 20 Kr and 22.5 Kr treatments where the survival of the slow growing seedlings was less due to high seedling mortality.

3.4. Seedling survival

In winged bean, of the seeds that germinated, all survived. In passion fruit, however, there was seedling mortality which increased with an increase in dosage (Table 4). The effect was most severe in the 25 Kr treatment in which all the seedlings died by the third week. In the 20 Kr and 22.5 Kr treatments, survivals were 47.4% and 48.4% respectively at 3 weeks after germination. At 5 weeks after germination, survivals were highest in the control (88.2%) and 15 Kr (86%) treatments but in the 20 Kr and 22.5 Kr treatments the survival had reduced further to 21.8% and 27.2%.

TABLE 4. The influence of irradiation treatments on the percentage survival of passion fruit seedlings during the first five weeks of growth.

Week	Control	Dosage (Kr)				
		15	17.5	20	22.5	25
1	100	100	100	100	100	100
2	97.6	98.7	93.7	93.7	75.7	60
3	94.8	94.9	89.5	47.7	48.4	—
4	89.6	91.1	78.1	37.5	33.3	—
5	88.2	86.0	67.1	21.8	27.2	—

3.5. Foliage aberrations in winged bean

Yellow spots were common on the cotyledons of all seedlings of the irradiated treatments. Their frequency and size were smaller in the 10 Kr and 20 Kr treatments compared to the higher doses. Two other leaf aberrancies that were observed in low frequencies were variegation and deformities. In the 10 Kr treatment, the first true leaf had these aberrations. In the 20 Kr and 30 Kr treatments they were confined to the first and second leaves whereas in the 40 Kr treatment they were found in the first three leaves.

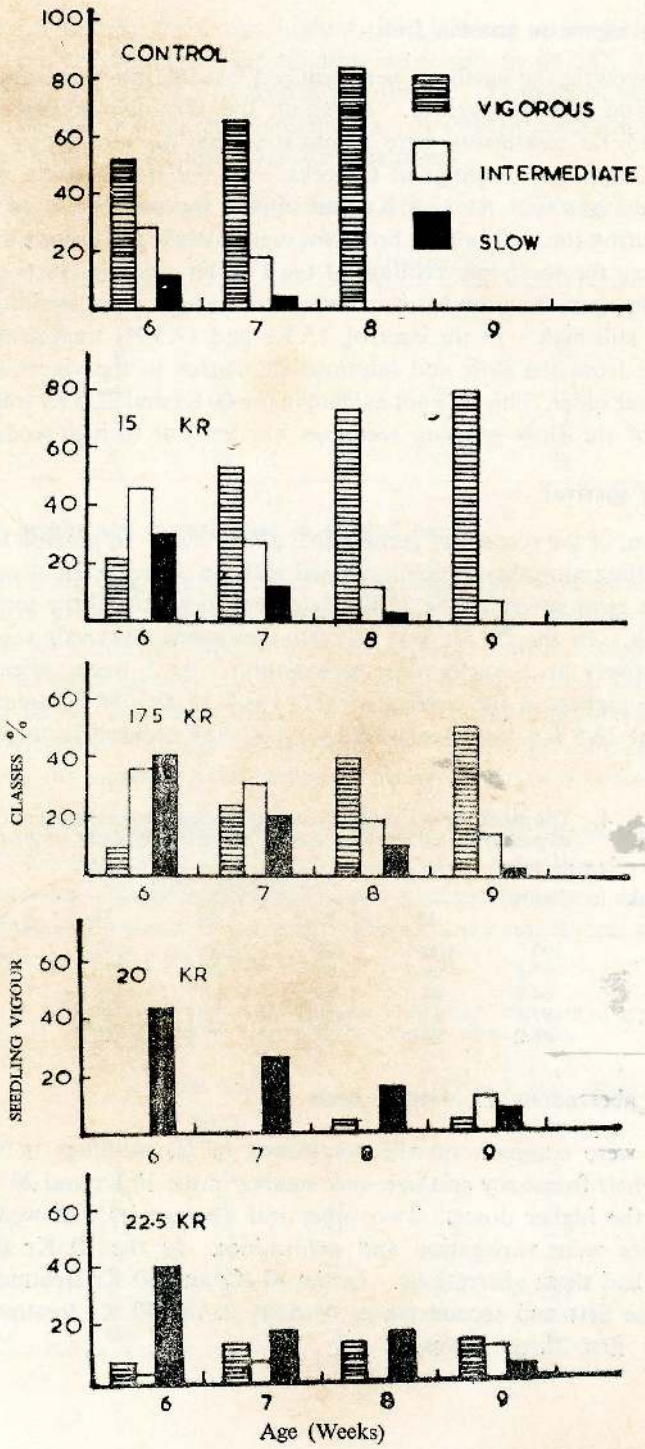

Figure 2. Changes in seedling vigour of passion fruit with age at different irradiation dosages.

4. Discussion

Winged bean and passion fruit showed a differential germination response to irradiation. The former was more tolerant to higher dosages of irradiation than passion fruit. The LD_{50} for winged bean was around 30 Kr to 40 Kr whereas in passion fruit it was between 17.5 Kr to 20 Kr. Differential germination responses to gamma irradiations among different crop species have been reported for castor,[5] jute,[1] red gram,[2] rice[4] and many other species.[3]

In their studies, jute had a high LD_{50} value of 120 Kr whereas red gram and rice had an LD_{50} value of 30 Kr. The ability of seeds, therefore, to tolerate different dosages of gamma irradiation is a species characteristic. But the age of seeds could alter the critical dosage levels, as shown in this study with winged bean, where a delay of 25 days in the second test gave a lower germination even at low irradiations, whereas in the less aged seeds of the first test, low dosages had a stimulatory effect on germination. Age also had an effect on seed vigour (Table 2) where irradiated fresh seeds germinated faster than aged seeds even at high dosages of irradiation.

Irradiation above 20 Kr were detrimental to passion fruit. This confirms the results of Tone and Desai[7] where a similar effect was observed for *P. edulis* and *P. foetida*. A detrimental effect in winged bean however was observed at a much higher dosage of 50 Kr.

Stimulation of germination in winged bean was found in treatments irradiated at 10 Kr to 30 Kr. This was not evident in passion fruit. Since passion fruit has a lower tolerance to gamma irradiation, stimulatory effects if any may show up at lower dosages than the levels used in our study as has been reported by Tone and Desai where dosages of 1 Kr to 2.5 Kr induced higher germination and survival than at higher doses. Stimulation of germination has been reported by the use of gamma irradiation on castor[5] and X-rays on bean[6] at a range of 7 to 14 Kr. Germination *per se* would not be an adequate criterion to determine the critical dosage range in some species. For example, while in winged bean all seeds that germinated survived, it was not so in passion fruit in which the proportion that survived at 5 weeks in the 20 Kr and 22.5 Kr treatments had decreased to 25 per cent of the total that germinated. The ability to survive in irradiated material seems to depend on the rate of growth of the species. Passion fruit being less vigorous as demonstrated during its germination and growth during the first five weeks, appears to succumb more easily to irradiation than the quick germinating and fast growing winged bean. Even in the rapidly growing winged bean, the influence of increased dosages on the vigour of growth during the first three weeks was evident, where irradiations of 30 Kr and above lowered the vigour of growth, but the growth rates were still high enough for the seedlings to pass the critical stage of survival.

In both species, it was found that if the seedlings continued to maintain growth during the initial critical period, they were observed subsequently in the field to pick up growth rapidly and it was difficult to distinguish between the slow growing seedlings of the high dosage irradiation treatments and the control. Apparently the effect of irradiations seems to wear off as the plants grew larger. Due to the slower growth of passion fruit, this effect was observed more clearly, where with time, there was a shift of plants that had slow and intermediate rates of growth to the vigorous category (Figure 2). This observation would suggest that when passion fruit seeds are irradiated for mutation and breeding studies, the intermediate and slow growing seedlings which may be the ones suspect with pronounced dosage effects should receive greater care in the nursery and they should be transplanted in the field later unlike in conventional transplantings.

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References

1. Joshua, D. C., Thakase, R. C., & Rao, N. S. (1972) *Indian J. Genet, Pl. Breed.* **32** : 340-344.
2. Khan, W. M. A., Sivasamy, N. & Ramaswamy, K. R. (1973) *Madras agric. J.* **60** : 406-407.
3. Moh, C. C. & Alan, J. J. (1974) *Turrialba,* **24** : 156-159.
4. Purushothaman, G. (1969). *Madras agric. J.* **56** : 110-119.
5. Raj, A. S. & Rao, B. V. R. (1963) *Madras agric. J.* **50** : 274-278.
6. Swarup, V. & Gill, M. S. (1968) *Indian J. Genet. Pl. Breed.* **28** : 44-58.
7. Tone, S. G. & Desai, N. P. R. (1975). *Curr. Sci.* **44** : 112-113.

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Variations in the Composition of Oil in Citronella

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Abstract : Commercial oil of citronella in Sri Lanka is distilled mainly from 'lenabatu' grass. In citronella plantations some mixed populations of 'lenabatu' and 'mahapengiri' types are found. Selections among these enabled eleven strains to be located. The propagation of these strains and the investigation of the essential oils distilled from them using gas liquid chromatography revealed differences among thirty-one of the chemical constitutents. In addition to the oil from the vegetative parts of the plants, the flowering parts also yielded essential oils which again showed differences from the leaf oils of the same plant and variations among the strains. Correlation studies provided values which have helped to explain the factors influencing the production of one group of components more than another. The variability of the chemical composition of oils that are reported have been observed to be in accord with the genetic difference of the strains.

1. Introduction

Sri Lanka is one of the principal citronella oil producing countries, and citronella has been cultivated in Sri Lanka for over a century. The two types of citronella oil sold in world market are the Java type and the Ceylon type, the former being produced from the Java variety called 'Mahapengiri' and the latter from the Ceylon variety called 'Lenabatu'. Botanically the two types, 'Mahapengiri' and 'Lenabatu' are derived from *Cymbopogon winterianus* Jowitt and *Cymbopogon nardus* (L) Rendel respectively.[1] It is believed that both types originated in Sri Lanka.[3] 'Mahapengiri' is now being grown in Java, Formosa, People's Republic of China, Haiti, Honduras, Taiwan, Guatemala and India. 'Lenabatu' is grown only in Sri Lanka. Although the bulk of the Sri Lanka oil is distilled from 'Lenabatu', 'Mahapengiri' type is also grown in certain areas. These two main types of grass could be distinguished morphologically, anatomically and chemically ; morphologically by the shape of leaves, length and width of leaves, length of sheath, colour of sheath and size of auricles ; anatomically by the nature of vascular bundles of leaf tissues, sclerenchyma arrangements, stomatal distribution their density and shape, type of epidermal appendages and their size (trichomes) ;[4] chemically by the composition of oil present in them.[6,14] It was believed that the main chemical differences between the oil from the two varieties were in the relative amounts of total acetylisables (total geraniol content) and the occurrence of compounds related to eugenol. GLC studies

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by Rogers and Toth showed that the two types of oil differ more markedly in their citronellol content then in the geraniol content.[10] Furthermore, a higher percentage of monoterpene hydrocarbons was observed in Lenabatu reported by Wijesekera and others.[14] The work on the composition of citronella oil conducted by the earlier workers was based on the analysis of commercially available citronella oil. Wijesekera *et al.* attempted to analyse the freshly distilled oil from Mahapengiri grown in plantations of Sri Lanka. Commercial Ceylon oil is distilled mainly from Lenabatu type, but there are areas where both Mahapengiri and Lenabatu are grown in mixtures and the oil from these plantations enters the oil of commerce. From earlier work it was observed that even in the oil of selected Mahapengiri types grown in Sri Lanka, a high percentage of terpene hydrocarbons occured though not as high as in Lenabatu. Thus, it is likely that the Sri Lanka Mahapengiri is a hybrid of both types. In other words, among the present cultivars of citronella grown in Sri Lanka there may be hybrids, mutants and polyploids yielding oil with different compositions. Some of these oils may be of better quality than the bulk oil exported from Sri Lanka which represents mostly Lenabatu oil.

Therefore with a view to selecting commercially desirable strains of citronella grass, a field survey was carried out in citronella growing areas. Preliminary selection of strains was based upon the morphological differences and these selections were subsequently tested for some of their morphological, anatomical, physiological and chemical features. In addition, a true Java variety was introduced from India and field experiments were conducted on both these selections and the Java variety. From the results of these experiments it was possible to isolate ten different selections of "strains".[4] Some of these strains possessed Lenabatu character, some Mahapengiri character, while others showed characteristics that were intermediate to the two types.[4,5] Morphological, anatomical and physiological character differences among the ten strains and the Java variety were recorded. Their yielding capacity of grass and oil also showed variation. Further investigations suggest the possibility of existence of polyploidy among some of these strains.[5] As such, a detailed study of constituents of oil extracted from different strains was undertaken in order to ascertain genetic influence on the composition of citronella oil.

2. Experimental

The selected ten strains (1—10), and the Java variety introduced from India (designated strain 11), were used for this investigation at the University Farm, Meewatura, Peradeniya. A completely randomized block design with ten treatments (strains) and three replicates was used for this experiment. Cross plot size was 4.5 × 4.5 metres. Planting was done at a spacing of 90 × 90 cm, with two tillers per hill. Fertilizer was applied with a basal dressing of 56 kg, 44.8 kg and 56 kg/ha followed by top dressings of 56 kg/ha of nitrogen at four monthly intervals.

The soil of the experimental site was a sandy loam, low in available nitrogen (515 kg/ha) and moderate in available phosphate (326 kg/P_2O_5/ha) and the pH was 6.1.

Harvests of grass and flower heads were taken at four monthly intervals and oil extraction was carried out after two days of drying under shade. Distillation of oil was carried out using a laboratory type water-steam still of glass. Leaf oil samples from 11 strains and flower oil samples from 8 strains were separately extracted and stored under refrigeration prior to GLC analysis.

Oil composition of first harvest were studied using Varian 1700 GLC equipment at the Ceylon Institute of Scientific and Industrial Research, Colombo. Analysis was carried out on samples of 0.3 μl. The column was held at 60° C for 4 minutes and then programmed at 4°C per minute to 200°C and held. Injector and detector temperatures were 200°C. Samples of oil from all three replicates of the trials were analysed separately for each strain. Identification of constituents was accomplished according to the method adopted by Wijesekera *et al.* Tentative peak identification was assigned by comparing the corrected retention volumes with those of authentic compounds. Chromatogram peak assignments of earlier workers, viz ; Wijesekera, Jayewardene and Fonseka, as well as the technique of peak enrichment were employed to confirm the identifications.

3. Results

Thirty-one peaks indicated the existence of a minimum of thirty-one different components in the oil of each strain. All three replicates gave identical chromatograms, indicating the consistency of composition of oil from the replicates of the trial. Between them the strains showed differences in composition of oil with quantitative variations among the thirty-one constituents of the leaf oil (Table 1). The magnitude of the differences varied widely between strains and the variability was highly prominent in the content of monoterpene alcohols, phenolics and in some of the terpene hydrocarbons namely camphene and limonene.

Flower oil also showed variations in composition between the eight strains (Table 2). The magnitude of differences in the percentage of constituents between the strains was less compared to that of the leaf oil. In all the strains, the percentages of monoterpene hydrocarbon compounds of flower oil were lower than those of leaf oil while the relative amount of monoterpene alcohols was higher in the flower oil. The citronellal content of flower oil was less than that of leaf oil except in strain one where it showed a higher value (9.90 and 0.97, respectively). Methyl isoeugenol was higher in the flower oil than in the leaf oil in five strains while it was low in three strains.

TABLE 1. Comparison of Constituents of Leaf Oil from Citronella Strains

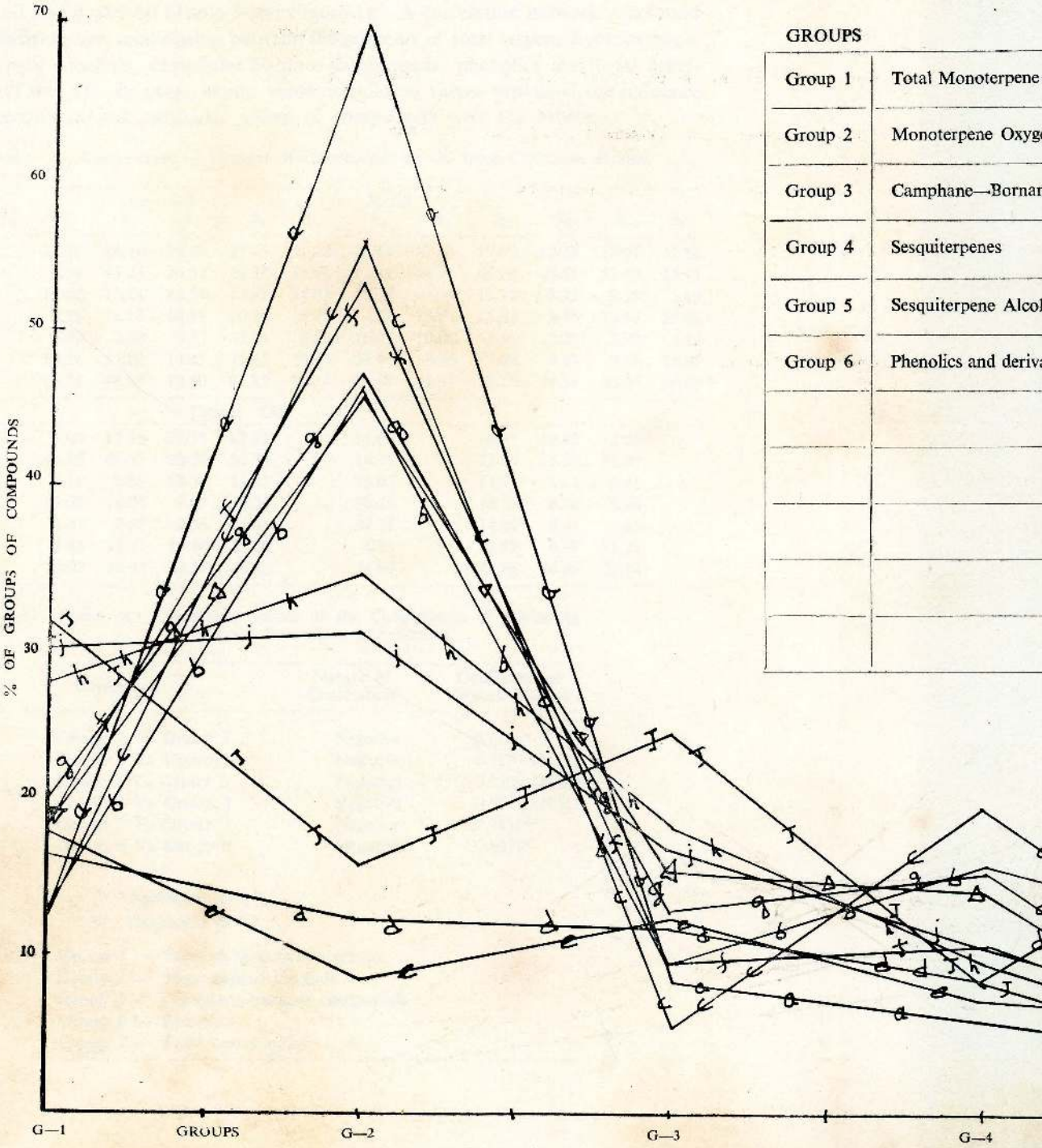
Peak No.	Compound	Leaf Oil Composition in % Strain 1	2	3	4	5	6	7	8	9	10	11
1	— Pinene Tricyclene	2.06	1.47	4.95	2.83	2.64	1.95	1.43	2.70	1.15	2.05	1.52
2	Camphene	4.19	5.39	3.93	8.62	11.55	3.31	2.79	6.95	3.25	4.42	1.55
3	— Myrcene	0.10	0.92	0.50	0.30	0.20	0.25	0.18	0.97	0.11	1.31	0.19
4	— Phellandrene Terpinene	0.71	1.13	1.20	0.95	1.14	0.70	0.50	0.67	0.47	0.80	0.99
5	Limonene	7.52	5.78	10.36	8.76	9.29	3.91	5.66	4.66	5.20	5.11	4.96
6	Cis Ocimene	1.33	2.29	5.50	3.40	3.39	3.12	0.90	2.14	1.26	2.19	2.77
7	— Terpinene	1.05	1.15	2.41	1.84	2.07	2.71	0.50	1.19	0.78	1.62	0.25
8	— Cymene Terpinolene	0.78	0.65	1.05	0.79	1.00	0.54	0.57	0.62	0.47	0.57	0.05
9	Unknown	0.06	0.09	0.39	0.00	0.17	0.25	0.13	0.26	0.21	0.04	0.46
10	Unknown	0.00	0.08	0.20	0.12	0.11	0.23	0.14	0.25	0.07	0.06	0.11
11	Unknown	0.16	0.21	0.33	0.00	0.25	0.34	0.18	0.18	0.07	0.04	0.17
12	Citronellal	0.97	3.91	5.65	4.80	0.98	0.37	0.66	8.44	33.96	8.22	1.85
13	Unknown	0.42	1.09	2.06	1.10	2.11	0.92	1.17	1.21	0.45	0.50	0.42
14	Linalool	1.01	1.63	2.20	1.25	2.52	2.85	1.27	1.44	0.82	0.88	2.10
15	— Caryophyllene	1.89	1.20	2.15	1.36	1.70	2.04	1.98	3.19	0.81	0.53	0.89
16	Unknown	0.93	0.37	1.21	0.85	0.94	0.57	1.17	0.83	0.39	0.57	0.39
17	Unknown	0.58	0.93	1.61	1.65	0.39	1.18	1.09	1.74	1.05	1.29	2.57
18	Unknown	2.80	2.30	3.72	2.16	1.84	3.69	2.33	2.37	0.78	2.40	3.19
19	Borneol	5.97	4.90	7.86	6.64	9.82	6.23	5.22	4.10	3.87	3.31	2.62
20	Citronellyl Acetate	0.96	1.55	2.69	2.21	1.34	1.25	1.21	1.67	0.93	2.32	4.43
21	Sesquiterpene	1.06	9.35	2.12	3.54	1.84	0.90	9.26	7.19	2.37	6.17	12.64
22	Citronellol	0.52	2.20	5.60	3.14	0.61	0.69	2.50	3.52	7.38	3.24	4.90
23	Nerol	0.92	0.67	1.49	1.03	0.00	0.00	1.62	0.78	0.29	1.03	1.11
24	Geraniol	0.13	33.12	9.26	18.56	1.95	2.08	36.82	29.76	23.78	37.83	44.24
25	Geranyl Butyrate	0.20	0.39	0.68	0.44	0.12	0.00	1.00	1.17	0.35	0.10	1.94
26[1]	Methyl Eugenol	0.00	0.00	0.53	0.00	0.52	0.95	0.53	0.00	0.00	3.28	0.00
26[2]	Nerolidol	0.61	0.53	2.81	1.05	0.52	13.02	3.52	0.45	0.10	1.62	3.43
27	Elemol	5.29	1.55	2.36	2.73	1.88	6.99	7.29	2.45	3.10	2.30	2.72
28	Unknown	34.41	0.75	2.09	1.30	5.47	12.89	7.78	0.97	1.33	2.41	1.19
29	Methyl Iso Eugenol	10.36	16.49	12.92	13.87	32.29	25.36	7.83	7.96	4.89	6.20	15.89
30	Unknown	1.07	1.98	1.68	3.79	1.05	0.70	1.00	0.28	0.08	0.89	1.29

TABLE 2. Comparison of Constituents of Flower Oil from Citronella Strains

Peak No.	Compound	1	2	3	4	5	6	7	8	9	10
1	α — Pinene & Tricyclene	0.00	0.77	2.31	1.84		1.13		1.68	1.11	0.86
2	Camphene	0.00	3.45	5.74	4.94		4.07		4.91	3.31	2.84
3	α — Myrcene	0.00	0.00	0.56	0.17		0.15		0.61	0.00	0.85
4	α — Phellandrene	0.00	0.00	1.05	0.53		0.54		0.51	0.84	0.40
5	Limonene	0.00	6.90	8.90	6.16		5.11		6.28	4.96	5.73
6	Ocimene	0.00	0.86	2.45	2.24		2.32		1.23	1.06	0.92
7	α — Terpinene	0.00	0.48	1.90	1.21		1.78		0.45	0.93	0.64
8	& — Cymene & Terpinolene	0.00	0.00	0.84	0.73		0.56		0.70	0.61	0.41
9	Unknown	0.77	0.00	0.00	1.05		0.00		0.00	0.00	0.00
10	Unknown	0.26	0.00	0.00	0.00		0.00		0.00	0.00	0.00
11	Unknown	0.99	0.00	0.00	0.00		0.22		0.00	0.00	0.00
12	Citronellal	9.90	1.68	5.68	1.05		0.45		2.41	14.04	2.87
13	Unknown	2.29	0.00	1.10	0.40		0.87		0.73	0.00	0.34
14	Linalool	2.70	0.96	2.10	0.66		4.46		1.52	1.52	1.10
15	β — Caryophyllene	1.76	1.68	1.54	1.59		4.86		3.62	1.77	3.27
16	Unknown	0.94	0.00	0.59	1.78		0.72		0.87	0.00	0.43
17	Unknown	1.59	0.00	1.26	0.62		0.95		1.21	1.54	1.00
18	Unknown	2.24	3.59	1.60	3.00		2.39		3.21	2.43	2.51
19	Borneol	7.15	4.79	6.25	7.13		4.87		4.78	4.39	4.15
20	Citronellyl Acetate	7.52	3.45	1.77	2.54		4.94		2.48	2.02	2.16
21	Sesquiterpene	3.49	10.78	2.88	3.35		1.34		6.88	2.70	4.56
22	Citronellol	8.71	3.16	3.77	1.54		1.11		2.52	10.39	3.31
23	Nerol	1.26	3.45	0.74	0.66		0.56		1.47	0.61	1.10
24	Geraniol	34.43	35.78	11.56	24.35		3.42		12.32	25.51	28.08
25	Geranyl Butyrate	1.49	0.00	1.12	0.25		0.17		1.49	0.00	2.29
26[1]	Methyl Eugenol	0.62	0.00	1.58	0.74		1.72		0.61	1.21	3.91
26[2]	Nerolidol	3.09	0.00	5.76	1.99		21.56		3.27	0.00	2.87
27	Elemol	1.38	2.68	3.86	3.82		12.69		11.60	6.41	4.74
28	Unknown	1.22	0.00	0.00	3.82		10.16		9.34	4.05	3.44
29	Methyl Isoeugenol	2.81	15.71	18.22	20.88		4.91		11.28	8.60	13.32
30	Unknown	1.39	0.00	5.47	0.95		1.94		2.03	0.00	1.94

For the convenience of comparison the constituents were grouped into seven groups :—

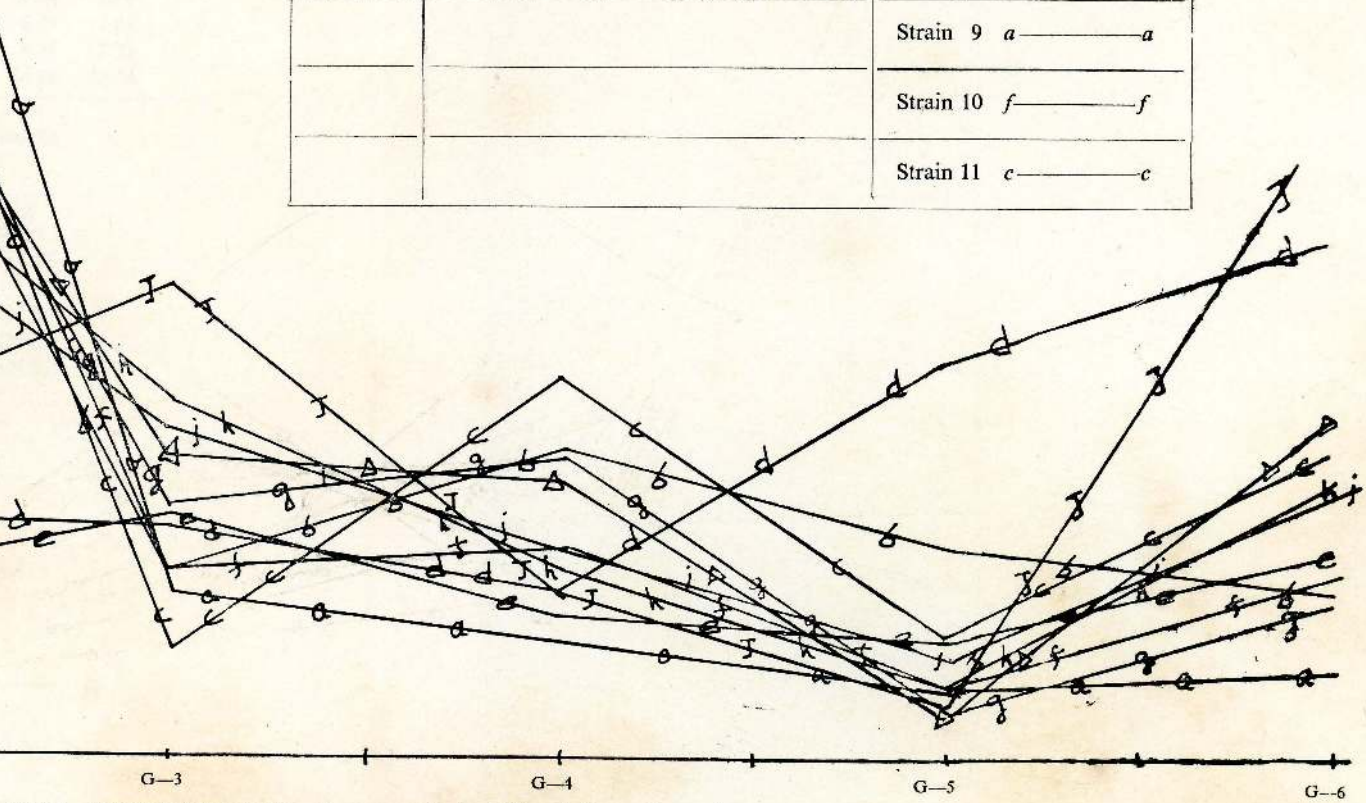
Group		Compounds	Peak No.
G 1.	Total Monoterpene Hydrocarbons	α — Pinene and Tricyclene	1
		Camphene	2
		Myrcene	3
		α — Phellandrene and α Terpinene	4
		Limonene	5
		Ocimene	6
		γ — Terpinene	7
		p — Cymene and Terpinolene	8
G 2.	Monoterpene Oxygenated compounds	Citronellal	12
		Citronellol	22
		Geraniol	24
		Linalool	14
		Borneol	19
G 3.	Camphene-Bornane Compounds	Camphene	2
		Borneol	19
		α — Pinene and Tricyclene	1
G 4.	Sesquiterpenes	β — Caryophyllene	15
		Unknown sesquiterpene	21
		Unknown sesquiterpene	16
		Unknown sesquiterpene	17
		Unknown sesquiterpene	18
G 5.	Sesquiterpene alcohols	Nerolidol	26^3
		Elemol	27
G 6.	Phenolics and derivatives	Methyleugenol	26^1
		Methyl isoeugenol	29
G 7.	Total acetylisables and esters	Citronellal	12
		Linalool	14
		Citronellyl acetate	20
		Borneol	19
		Citronellol	22
		Nerol	23
		Geranial	24
		Geranyl butyrate	25
		Nerolidol	26^3
		Elemol	27



GROUPS	
Group 1	Total Monoterpene
Group 2	Monoterpene Oxyg
Group 3	Camphane—Bornar
Group 4	Sesquiterpenes
Group 5	Sesquiterpene Alcol
Group 6	Phenolics and deriva

Figure 1. Percentage of groups of compounds in different citron

GROUPS		STRAINS
Group 1	Total Monoterpene Hydrocarbons	Strain 1 *e*——*e*
Group 2	Monoterpene Oxygenated Compounds	Strain 2 Δ——Δ
Group 3	Camphane—Bornane Compounds	Strain 3 *j*——*j*
Group 4	Sesquiterpenes	Strain 4 *h*——*h*
Group 5	Sesquiterpene Alcohols—Nerolidol —Elemol	Strain 5 *J*——*J*
Group 6	Phenolics and derivatives	Strain 6 *d*——*d*
		Strain 7 *b*——*b*
		Strain 8 *g*——*g*
		Strain 9 *a*——*a*
		Strain 10 *f*——*f*
		Strain 11 *c*——*c*



gure 1. Percentage of groups of compounds in different citronella strains.

The percentage of these groups of compounds varied greatly within the strains for leaf oil and flower oil (Table 3 and Figure 1). A correlation network was found which illustrates the relationship between the contents of total terpene hydrocarbons, monoterpene alcohols, camphene bornane compounds, phenolics and total acetylesables (Table 4). In other words, these correlation values explained the influence of production of one particular group of compounds over the others.

TABLE 3. Comparison of Groups of Compounds of Oil from Citronella Strains

Group %	Strain S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	S_{11}
			Leaf Oil								
1	17.76	18.10	29.90	27.49	31.22	16.49	12.53	19.90	12.69	18.07	12.28
2	8.59	45.24	30.57	34.39	15.88	12.22	46.47	47.26	69.81	53.48	55.71
3	12.22	15.24	16.74	13.91	24.01	11.49	9.44	13.75	8.27	9.78	5.69
4	7.26	14.15	10.81	10.34	8.41	8.38	15.83	15.32	5.36	10.96	19.62
5	5.90	2.08	5.17	5.81	2.40	20.01	10.81	2.90	3.20	3.92	6.15
6	10.36	17.02	13.45	21.62	32.81	26.31	8.36	7.96	4.89	9.28	15.89
7	16.56	48.82	40.60	41.85	19.74	33.48	61.31	53.78	74.58	60.85	69.40
			Flower Oil								
1	0.00	12.46	23.75	17.83		15.66		16.37	12.82	12.65	
2	62.89	46.37	29.36	34.73		14.31		23.55	55.85	37.87	
3	7.15	9.01	14.30	13.91		10.07		11.37	8.81	6.21	
4	10.02	16.05	7.87	10.34		10.26		15.79	8.44	7.96	
5	4.47	2.68	9.56	5.81		34.25		14.87	6.41	7.61	
6	3.43	15.71	19.80	21.62		6.63		11.89	9.81	17.23	
7	78.97	55.95	42.55	43.89		54.69		43.86	64.86	52.64	

TABLE 4. Correlation values of the Constituents of Citronella Leaf Oil Between the 11 Strains

Compound	Nature of Correlation	Coefficient of Correlation (r)
Group 1 Vs Group 7	Negative	0.6136*
Group 1 Vs Group 2	Negative	0.5117 (N.S.)
Linalool Vs Group 2	Negative	0.5200 (N.S.)
Group 3 Vs Group 2	Negative	0.5745 (N.S.)
Group 3 Vs Group 7	Negative	0.7110**
Group 6 Vs Group 7	Negative	0.6079*

* Significant at 5%
** Significant at 1%

Group 1 — Total terpene hydrocarbons
Group 2 — Monoterpene alcohols
Group 3 — Camphene-bornane compounds
Group 6 — Phenolics
Group 7 — Total acetylisables

Total terpene hydrocarbons had a negative correlation significant at 5% level over the contents of total acetylisables while it did not have any significant correlation over the content of monoterpene alcohols. Similarly, the camphene-bornane compound group had a negative correlation significant at 1% level with total acetylisables and esters while it did not have significant correlation with total monoterpene alcohols. Linalool had no significant correlation with total monoterpene alcohols. Phenolics showed a negative correlation significant at 1% with total acetylisables.

4. Discussion

Most of the constituents of citronella oil were terpenes and their oxygenated compounds. Within a given genus of a number of plant families studied, the terpene appear to be distributed rather selectively within certain species. If the environmental factors such as soil and climate are kept constant, this distribution is probably under specific genetic control. For instance, in the genus *Monarda*, Fujita[2] found that one species *M. didyma* contained large quantities of linalool and little or no phenolic or aromatic constituents such as p-cymene or thymol, whereas in other species of this genus the reverse was found.[2] Fujita developed from these observations a biogenetic scheme envisioning linalool as the parent material of the cyclic intermediates. Further, the influence of specific genetic factors is markedly apparent in the studies of Penfold and Morrison[8] on the eucalyptus genus. Their study showed that 230 species of eucalyptus could be grouped into four types-those producing largely (1) cineole (2) piperitone (3) phellandrene or (4) acyclic terpenes like geraniol. In a group of such trees growing a few feet apart some contained essential oil consisting predominantly of cineole, others contained predominantly piperitone.[7] Similarly, Mirov[7] in a study of the genus *Pinus* gives examples where individual species could not be differentiated morphologically, but differed in terpene content. With regard to citronella the eleven strains originated from two species namely *Cymbopogon nardus* and *Cymbopogon winterianus* and they were proved to be different morphologically, anatomically and cytologically.[4]

Thus their variability in terpene content of oil could be expected and variability of the oil composition could be attributed to their genetic differences. Examination of the essential oil content of various *Mentha* species suggested that a genetic factor was responsible for high menthol content, where genes from two species were found essential.[9] Reitsema[9] has shown evidence for the presence or absence of a particular enzyme system which is genetically controlled and which may influence the terpene content of certain mint plant species. Similar views could also be envisaged in citronella strains, as the pattern of terpene distribution in different strains showed consistency. One may expect the feasibility of the existence of a pair of genes or more or even an entire chromosome responsible for the production of the enzyme that controls the biogenesis of these compounds in citronella species.

A general similarity could be observed in the composition of oil in strains 9, 10, 11 and 8 as against strains 3, 4, 5, 6 while strains 2 and 7 behave intermediate to those two groups. Strain 1 forms a separate group by itself in this respect. Therefore one could expect that the genes responsible for the production of terpenes are distributed in a regular, but unknown pattern in these strains of citronella. This is further supported by the fact that these strains exhibit polyploidy.[5]

The study of correlation coefficient of group of constituents show interesting predictions over the biogenesis of these compounds. According to Wijesekera *et al.*,[13] the possible pathways in the formation of monoterpenoids in citronella too follow the usual sequence ; leading to the formation of camphene bornane group tgroup 3) compounds in bigger quantities which will deplete the formation of mono-(erpene alcohols (group 2). Our correlation values (Table 4) showed no significant linear correlation between these two groups. At the same time camphene bornane compounds showed a highly significant negative correlation with total acetylisables which is the value of monoterpene alcohols plus other oxygenated compounds. Thus one could arrive at the fact that in citronella the production of camphene bornane compounds might have influence over the pathways where the other oxygenated compounds are produced from the monoterpene alcohols. This may suggest that, at the expense of latter the former is synthesized.

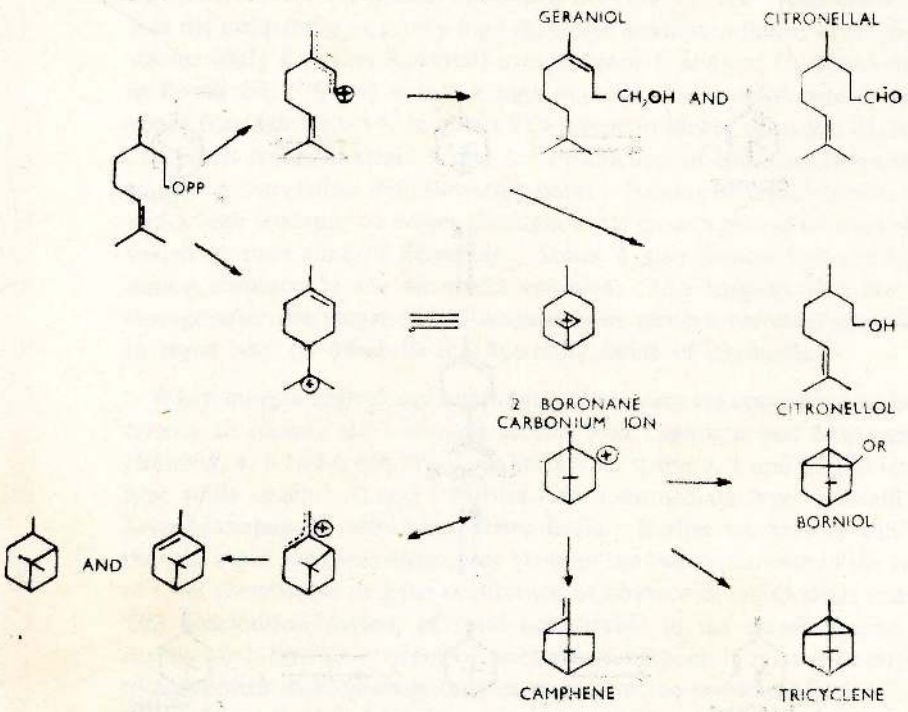


Figure 2. Possible pathways in the performance of monoterpenoids of Citronella.

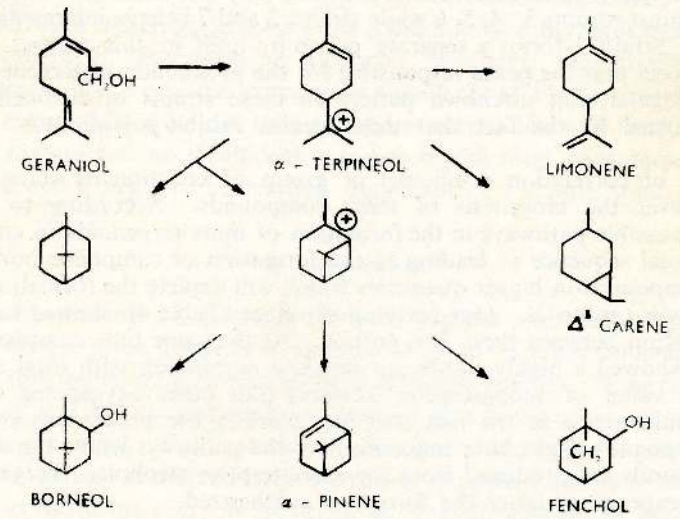


Figure 3. Ionic mechanisms in the biogenesis of monoterpenes (Ruzicka)

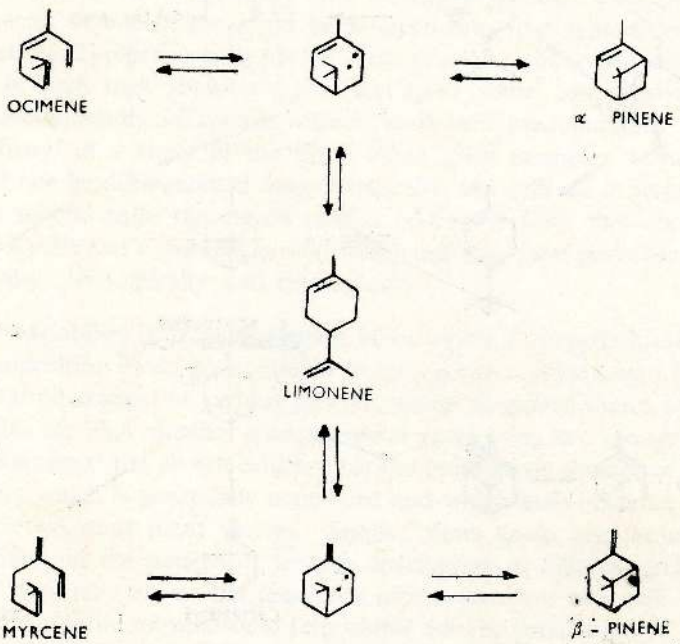


Figure 4. Radical mechanisms in the biogenesis of monoterpenes (Ruzicka).

Similarly the content of total monoterpene hydrocarbons (Group I), which again includes the camphane-bornane compounds except borneol had significant negative correlation with total acetylisables whereas total hydrocarbons had no linear correlation with total monoterpene alcohols. In other words, production of total hydrocarbons might have control over the production of total acetylisable but not when considered individually for terpene alcohols and oxygenated compounds. This prediction is in accord with the earlier experiments of Charabot[12] who indicated that terpane alcohols are the first condensation products that arise in higher plants and that esters and terpene hydrocarbons are derived from them by acylation and dehydration, respectively. This is in accord with the classical concepts of Ruzicka,[11] in developing the "biogenetic isoprene rule". Tracer studies would throw considerable light on the biosynthetic mechanisms.

In commercial cultivation of citronella, usually the harvests of grass are taken before flowering and about six inches above the ground level. The high total acetylisable content and low hydrocarbon content in flower oil as against the leaf oil suggests that flower head contains oil of better utility. In fact, in strain 1, flower oil showed only a trace amount of hydrocarbons while the total acetylisables was increased almost five-fold as compared with the leaf oil. Another interesting finding was the occurrence of a very high nerolidol content in flower oil of strain 6. All the strains (only 8 strains flowered) except strain 1, showed increased nerolidol content in flower oil. Strain 6 had a high content of nerolidol even in leaf oil (13% in strain 6 as against 0.1% in strain 9) whereas in flower oil it had 21.56% of nerolidol as against traces in strain 9 and 2. Production of this sesquiterpene alcohol seems to have a correlation with flowering habit. Among all the citronella strains, strain 6 had a high tendency to flower throughout its growth period whereas the other strains varied in their time of flowering. Strain 6 also flowers first during the flowering season common to the citronella varieties. This suggests that the biogenesis and storage after the biogenesis of sesquiterpene alcohol nerolidol are closely connected in some way or other to the flowering habit of citronella.

When morphological and anatomical characters are considered to be the important criteria to classify the citronella strains into Lenabatu and Mahapengiri types, the strains 3, 4, 5 and 6 fall into Lenabatu type, strain 9, 8 and 10 fall into Mahapengiri type while strain 1, 2 and 7 fall into the intermediate type.[4] Strain 11 was typical Java Mahapengiri introduced from India. Earlier workers in this field observed that the main chemical differences between the two types were in the relative amounts of total acetylisable and the occurrence or absence of compounds related to eugenol. The distribution pattern of total acetylisable in the eleven strains confirmed the earlier work but the content of phenolics (compounds related to eugenol) did seem to agree with their findings only in respect to the introduced Java pengiri strain 11. In fact, the Ceylon Mahapengiri strains followed the pattern (Table 1) reported by the earlier workers whereas the strain 11 had fairly high phenolic contents (15.8%)

which was equivalent to that of some of Lenabatu strains. Similar problems arose in the citronellal and total hydrocarbon content. According to Wijesekera,[14] and Rogers and Toth,[10] the Java variety contains a high proportion of citronellal, citronellol and lower proportions of terpene hydrocarbons, but strain 11 had lower content of citronellal and the total hydrocarbon content was found to be equivalent to the typical Ceylon Mahapengiri in our investigations. Wijesekera *et al.*[14] indicated that even the Ceylon Mahapengiri contains higher proportion of terpene hydrocarbons than that found in the Java oil available in the world market. They suspected that the sample of oil used may have been previously deterpinated,[14] since these samples were obtained from the commercial sources abroad. Another possibility for such a situation may be that the Java pengiri plant introduced for our investigations also might be one of the chemotypes that might be present in countries where Java pengiri citronella type are cultivated continuously. In other words, the commercial plantations in those countries may have mixed populations of several Java strains similar to our local conditions for Lenabatu.

The borneol content was low in strain 11, Ceylon Mahapengiri strain 8, 9 and 10 which agree with these findings of earlier workers.

The above chemical differences attributed to the differences in their genetic nature will be useful in plant improvement programmes and the establishment of commercial plantations. The consistently wide variation of chemical composition of oil between strains of citronella might be useful also in the chemical industry especially for perfumery and cosmetic manufacture.

References

1. ABEYWICKREMA, B. A. (1959). *Ceylon J. Sci. biol. Sci.* **2**: (2) : 132.
2. FUJITA, J. (1951). *In Fundamental Studies of Essential Oils* (in Japanese). *The Ogawa Perfumery Times*, Ogawa and Co. Ltd., Osaka and Tokyo, No. 202, September 1951, p. 502.
3. GUENTHER, E. (1950). *The Essential Oils*, **4** : 67, Van Nostrand, New York.
4. IRUTHAYATHAS, E. D. & HERATH, H. M. W. (1975). *Investigations on Lemongrass and Citronella, Proc. Agric. Research Seminar Series*, Faculty of Agriculture, University of Sri Lanka, Peradeniya, Sri Lanka.
5. IRUTHAYATHAS, E. D. & HERATH, H. M. W. (1976). *Characterization and Identification of Citronella Cultivars*, (paper under preparation).
6. JOWITT, J. F. (1908). *The Volatile Oils*. GILDMEISTER, A. & HOFFMAN, A. eds. KREMERE, E. Trans., 2nd Edn. **2**: 217-243, *Ann. R. bot. Gdns. Peradeniya*, **41**: 185.
7. NICHOLAS, H. J. (1963). *The Biogenesis of Terpenes in Plants*, BERNFELD, P. (1963). *Biogenesis of Natural Compounds*, Pergamon Press Ltd., United Kingdom Edn. 640-687.
8. PENFOLD, A. R. & MORRISON, F. R. J. (1927). *Proc. R. Soc. N.S.W.* **61**: 54.
9. REITSEMA, R. H. (1958). *J. Am. pharm. Ass.* Edn. **47**: 267.
10. ROGERS, J. A. & TOTH, Z. E. (1961). *Proc. Sci. Sect. Toilet Goods Association* **35** : 29.
11. RUZICKA, L. (1953). *Experientia* **9**: 257.
12. SINGLETON, F. (1931). *Chemy Ind. London*, **50**: 989.
13. WIJESEKERA, R. O. B. (1973). *A Second Look at Citronella, Proc. Inst. Chem. Cey. 2nd Ann. Sess.* 17-20.
14. WIJESEKERA, R. O. B., JAYEWARDENE, A. L. & FONSEKA, B. D. (1973). *Varietal Differences in the Constituents of Citronella Oil, Phyt chemistry*, 1973, **12** : 2697-2704.

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Residual Toxicity of some Herbicides

(i) 2, 4–D, MCPA and TCA

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Abstract : Residual toxicity studies of 3 herbicides viz. 2,4-Dichlorophenoxy acetic acid, 2-methyl 4-Chlorophenoxy acetic acid and Trichloroacetic acid in four common soil groups : Reddish Brown Earth, Reddish Brown Latasolic, Immature Brown Loam and Low-humic Gley, indicate that the herbicidal effect of the compounds examined decrease during incubation, more rapidly in LHG soils than in others. 2, 4-D and MCPA decomposed faster than TCA. The residual toxicity of herbicides examined except TCA decreased at a slower rate under flooded conditions than under unflooded conditions. Studies carried out with autoclaved soils show that microbial activity is responsible for the decrease in toxicity except in TCA. Residual toxicity decreased more rapidly in soils previously incubated with these herbicides. Leaching tests indicate that the three herbicides tend to get adsorbed mostly in the first 3 in. of the soil except in LHG where accumulations were more in the 1 to 2 in. layer.

1. Introduction

Since 1895 when the herbicidal property of $CuSO_4$ was discovered by Bennet, a large number of herbicides, with different degrees of selectivity have been developed, to be utilized in our endeavours to achieve a higher level of food production.

The ultimate recipient of most of the herbicides is the soil, which is a complex mixture of organic and inorganic particles inhabited by microscopic and macroscopic organisms. The molecules of the herbicide that enter the soil are subjected to physical and chemical changes. Physically, the phytotoxic compounds get adsorbed on soil colloidal particles and this process has been shown to be influenced by a number of factors related to the nature of the herbicide molecule[3] and the soil.[8] Desorption of the adsorbed molecules also take place as shown by Williams[23] and Talbert and Fletchell.[22]

Chemical changes of herbicide molecules are brought about by chemical and biological factors. Armstrong *et al.*[4] and Zaki *et al.*[24] have shown chemical transformations of the soil incorporated herbicides while decomposition of herbicides by soil microorganisms has been demonstrated by a number of workers.[16,17,18] Microorganisms are known to utilize these organic molecules as a source of energy.[12,15] However, some compounds such as 2, 3, 6—TBA are recalcitrant[2] and are known to remain undecomposed in soil over long periods.[9,10]

Those herbicides that get decomposed by soil microorganisms also remain in the soil for varying periods prior to their decomposition. This period called the lag period, depends on the nature of the soil and the compound.[5]

In view of these findings, a study of the residual toxicity of herbicides commonly used is of importance in obtaining the maximum benefit of herbicides applied and also in controlling environmental pollution. The studies reported in this paper were carried out to examine the residual toxicity of some of the commonly used herbicides in Sri Lanka.

2. Materials and Methods

2.1. Materials

The commercially available compounds of the following herbicides were used :

1. 2,4—Dichlorophenoxy acetic acid amine salt (2,4—D).
2. A mixture of sodium and potassium salt of 2 methyl 4—chlorophenoxy acetic acid (MCPA).
3. Trichloro acetic acid sodium salt (TCA).

Four soil groups were used in this study and their characteristics are indicated in Table 1.

TABLE 1. Some characteristics of the soils used in the study

Type of Soil	% sand	% silt	% clay	% o.matter	pH
Reddish Brown Earth	38.5	18.5	43.0	0.65	7.8
Reddish Brown Latosolic	36.5	15.3	49.2	1.14	5.9
Immature Brown Loam	40.8	24.6	34.6	1.28	5.7
Low-Humic gley	28.5	18.5	52.7	2.06	7.2

2.2. Methods

2.2.1. *Experiment* 1. *Residual toxicity of herbicides under unflooded conditions.*

250 g of soil of each group was separately mixed with herbicide solutions to give the following concentration in the soil.

*2, 4—D	1.5	ppm
*MCPA—	2.0	ppm
*TCA—	10	ppm

* Some characteristics of these compounds are given in the appendix.

The moisture content was brought to 50% field capacity and the soil-herbicide mixture was incubated at room temperature. Three replicates were included for each soil group. At fortnightly intervals, the residual toxicity of the soil-herbicide mixture was determined by bio-assay tests (5) using mustard as a test plant. Incubation was continued over a period of 13 weeks.

2.2.2. *Experiment* 2. *Residual toxicity of herbicides under flooded conditions*

Soils were mixed with herbicides as in Experiment 1 and were incubated under similar conditions except for the fact that flooded conditions were maintained by keeping water 1 in above the surface of soil. Residual toxicity of the incubated soils was determined at fortnightly intervals over a period of 13 weeks by bio-assay tests.

2.2.3. *Experiments* 3 *and* 4. *Residual toxicity of herbicides in sterile soils.*

Similar to Experiments 1 and 2 respectively except for the fact that sterile soils (soils heated to 150°C for 48 hours) were used.

2.2.4. *Experiment* 5. *Residual toxicity of herbicides in soils previously treated with the herbicides.*

Soils used in Experiment 1 were kept moist over a period of one year. These soils were re-incubated with herbicides added as in Experiment 1 and the residual toxicity was determined by bio-assay tests at fortnightly intervals.

2.2.5. *Experiment* 6. *Residual toxicity of herbicides in the field.*

This experiment was conducted on field scale at Kundasale. The herbicides were applied to weed-free plots 15 ft × 15 ft at recommended rates indicated in the appendix. The number of weeds in these plots was determined at fortnightly intervals.

2.2.6. *Experiment* 7. *Adsorption of herbicides.*

100 ml of the herbicide solution was leached through a soil column 4 in long. (It was found that 100 ml of solution was just sufficient to wet the whole soil column). The soil column was removed as 1 in blocks and the residual toxicity of these blocks was examined by bio-assay tests.

3. Results and Discussion

3.1. *Experiment* 1.

The results obtained in Experiment 1 are given in Table 2. These results indicate that there is an initial drop in the concentration of herbicides which could be attributed to adsorption on clay and organic matter in the soils used. Adsorption of herbicides in soils has been reported by a number of workers.[8]

TABLE 2. Residual concentration of the herbicides in soils incubated under unflooded condition at fortnightly intervals in ppm

	Weeks							
	0	1	3	5	7	9	11	13
2,4—D								
RBE	1.5	1.0	1.0	1.0	0.8	0.6	0.4	0.2
RBL	1.5	1.0	1.0	1.0	0.9	0.8	0.7	0.6
IBL	1.5	1.0	1.0	1.0	0.9	0.8	0.6	0.4
LHG	1.5	0.8	0.7	0.6	0.5	0.3	0.1	0.05
MCPA								
RBE	2.0	1.0	1.0	1.0	0.8	0.6	0.4	0.2
RBL	2.0	1.0	1.0	1.0	0.9	0.8	0.7	0.6
IBL	2.0	1.0	1.0	0.8	0.7	0.6	0.4	0.4
LHG	2.0	0.8	0.8	0.6	0.5	0.4	0.2	0.1
TCA								
RBE	10	8	8	8	6	4	4	4
RBL	10	8	8	8	6	6	6	4
IBL	10	8	8	6	6	6	6	4
LHG	10	8	8	6	6	4	4	2

All the three herbicides examined have decomposed in the four soils during the incubation period, decomposition being most rapid in LHG soil. This is likely to be due to higher microbial activity in the LHG soil brought about by the relatively high organic matter content. It is known that decomposition of herbicides in soil is brought about mainly by microorganisms.[2,5,7]

In all soils other than LHG, 2,4-D, MCPA and TCA have begun to decompose after the fifth week ; but in LHG, decomposition has started at an earlier stage. Previous studies, too, have shown rapid decomposition of these herbicides.[14,19] The decomposition of 2,4-D and MCPA is slower in RBL and IBL soils ; this is possibily due to the relatively low pH of these soils. It has been reported that microbial activity is less in acidic soils.[1] However, the rate of decomposition of TCA appears to be more or less the same in all the soils. This is likely to be due to chemical factors being more dominant in the decompositions of this compound. Chemical transformations of soil incorporated herbicides have been reported.[4,24]

3.2. *Experiment* 2.

The results of this experiment (Table 3) indicate an initial reduction in the concentration of the herbicides as in Experiment 1. Subsequently, however, there is a relatively small drop in the concentration of the herbicides except TCA. The decreased microbial activity in the flooded soils due to anaerobic conditions prevailing is likely to have resulted in the little decomposition of the herbicides except TCA. TCA has decomposed faster under flooded condition than under unflooded condition indicating that anaerobic soil microorganisms favour its decomposition. Anaerobic biodegradation of chlorinated hydrocarbon insecticides has shown to be favoured by a fall in the redox potential.[20]

TABLE 3. Residual concentration of the herbicides in soils incubated under flooded condition at fortnightly intervals in ppm.

	Weeks							
	0	1	3	5	7	9	11	13
2, 4—D								
RBE	1.5	1.0	1.0	1.0	1.0	1.0	0.8	0.8
RBL	1.5	1.0	1.0	1.0	1.0	1.0	1.0	0.8
IBL	1.5	1.0	1.0	1.0	1.0	1.0	0.8	0.6
LHG	1.5	1.0	1.0	1.0	1.0	0.8	0.8	0.6
MCPA								
RBE	2.0	1.5	1.5	1.5	1.0	1.0	1.0	1.0
RBL	2.0	1.5	1.0	1.0	1.0	1.0	1.0	1.0
IBL	2.0	1.5	1.0	1.0	1.0	1.0	1.0	1.0
LHG	2.0	1.5	1.0	1.0	1.0	0.8	0.8	0.8
TCA								
RBE	10	10	8	6	0	0	0	0
RBL	10	10	8	4	0	0	0	0
IBL	10	10	8	6	4	2	0	0
LHG	10	10	8	4	4	10	10	10

Trichloroacetate during the course of its decomposition appears to have formed another toxic compound in LHG soils in the ninth week of incubation. This compound has a toxicity equivalent to 10 ppm of TCA and has not decomposed in the subsequent 6 weeks. Audus has reported of a similar process with 2, 4 dichlorophenoxyethyl sulphate.[6]

3.3. *Experiment* 3.

Residual concentrations of the three herbicides incubated in sterile soils under unflooded condition (Table 4) show that almost no decomposition has taken place during the incubation period suggesting that the soil microorganisms are responsible for the decomposition of these compounds. Audus[5] also has shown that decomposition of agro-chemicals in soil is mostly brought about by organisms.

3.4. *Experiment* 4.

Results of Experiment 4 (Table 5) are similar to that in Experiment 3 but TCA incorporated soils show lower toxicity than in Experiment 3 during the latter part of incubation period. This suggests that TCA has undergone chemical changes under flooded condition probably due to non-biological factors resulting in a decrease in the toxicity level. Zaki *et al.*[24] also have reported of such non-biological chemical changes of herbicides in soils.

3.5. *Experiment* 5.

Investigations by Audus[7] have shown that decomposition of herbicides is rapid in soils previously treated with them. This could be attributed to adaptation of soil microorganisms as suggested by Cohn and Monod[11] and Hirsch and Alexander[13] or due to the evolution of strains capable of decomposing the compounds as shown by Kearney *et al.*[17]

TABLE 4. Residual concentration of the herbicides incubated in sterile soils under unflooded condition at fortnightly intervals in ppm.

	Weeks							
	0	1	3	5	7	9	11	13
2, 4—D								
RBE	1.5	1.0	1.0	1.0	1.0	1.0	1.0	0.8
RBL	1.5	1.0	1.0	1.0	1.0	1.0	1.0	0.8
IBL	1.5	1.0	1.0	1.0	1.0	1.0	1.0	0.8
LHG	1.5	1.0	1.0	1.0	1.0	1.0	1.0	0.8
MCPA								
RBE	2.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
RBL	2.0	1.0	1.0	1.0	1.0	1.0	1.0	0.8
IBL	2.0	1.0	1.0	1.0	1.0	1.0	1.0	0.8
LHG	2.0	1.0	1.0	1.0	1.0	1.0	1.0	0.8
TCA								
RBE	10	8	8	8	8	8	8	6
RBL	10	8	8	8	8	8	6	6
IBL	10	8	8	8	8	8	6	6
LHG	10	8	8	8	8	8	8	6

TABLE 5. Residual concentration of the herbicides incubated in sterile soils under flooded condition at fortnightly intervals in ppm.

	Weeks							
	0	1	3	5	7	9	11	13
2, 4—D								
RBE	1.5	1.0	1.0	1.0	1.0	1.0	1.0	0.8
RBL	1.5	1.0	1.0	1.0	1.0	1.0	1.0	0.8
IBL	1.5	1.0	1.0	1.0	1.0	1.0	1.0	0.8
LHG	1.5	1.0	1.0	1.0	1.0	1.0	1.0	0.8
MCPA								
RBE	2.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
RBL	2.0	1.0	1.0	1.0	1.0	1.0	1.0	0.8
IBL	2.0	1.0	1.0	1.0	1.0	1.0	1.0	0.8
LHG	2.0	1.0	1.0	1.0	1.0	1.0	1.0	0.8
TCA								
RBE	10	8	8	6	4	4	2	2
RBL	10	8	8	6	6	4	2	2
IBL	10	8	8	6	6	4	2	2
LHG	10	8	8	4	4	4	2	2

The results of the Experiment 5 (Table 6) show that the findings of Audus[5] could be applied to the three herbicides examined. However TCA in LHG soils appear to have formed a toxic compound during the latter part of incubation like in the case of Experiment 2.

TABLE 6. Residual concentration of the herbicides incubated in soils previously treated with the herbicides in ppm.

	Weeks							
	0	1	3	5	7	9	11	13
2, 4—D								
RBE	1.5	1.0	0.5	0.2	0	0	0	0
RBL	1.5	1.0	0.5	0.2	0	0	0	0
IBL	1.5	1.0	0.5	0.2	0	0	0	0
LHG	1.5	1.0	0.5	0.2	0	0	0	0
MCPA								
RBE	2.0	1.0	0.1	0	0	0	—	—
RBL	2.0	1.0	0.2	0	0	0	—	—
IBL	2.0	1.0	0.2	0	0	0	—	—
LHG	2.0	1.0	0.2	0	0	0	—	—
TCA								
RBE	10	8	6	2	0	0	0	—
RBL	10	8	4	0	0	0	0	—
IBL	10	8	4	0	0	0	0	—
LHG	10	8	4	0	10	10	10	—

3.6. *Experiment* 6.

Results of Experiment 6 (Table 7) which was carried out at Kundasale indicate that the three herbicides tested have degraded within the 12 week period confirming the findings of Experiment 1.

TABLE 7. Number of weeds per 5 square yards at fortnightly intervals in plots treated with herbicides

Herbicide	Average number of weeds per 5 square yards (av. of 3) Weeks after application of the herbicide					
	2 Weeks	4 Weeks	6 Weeks	8 Weeks	10 Weeks	12 Weeks
2, 4—D	10	15	22	26	32	44
MCPA	9	17	24	30	38	49
TCA	12	18	30	40	48	51

3.7. *Experiment* 7.

The leaching experiments carried out (Table 8) indicate that all the compounds studied tend to remain mosuly in the 1 to 3 in. of the soil. Relatively higher adsorption of the three herbicides in the 1st inch of LHG is likely to be due to the high organic matter content of the soil. Sheets[21] has shown that organic matter is mostly responsible for adsorption of the organic pesticides. In addition to organic matter a number of other factors such as clay content, cation exchange capacity and pH are known to cause adsorption of agrochemicals in soils.[8]

TABLE 8. Concentration of the herbicides in ppm in soil columns leached with 100 ml of herbicide solution.

Herbicide		RRE	RBL	IBL	LHG
2, 4—D	0—1"	0.5	0.3	0.4	0.6
	1—2"	1.0	1.2	0.9	0.1
	2—3"	0.6	0.6	0.8	0.8
	3—4"	0.4	0.4	0.4	0.3
MCPA	0—1"	0.4	0.5	0.4	0.1
	1—2"	0.9	0.8	0.9	0.9
	2—3"	1.2	1.4	0.9	0.9
	3—4"	0.8	0.6	1.1	0.7
TCA	0—1"	2.0	2.0	4.0	5.0
	1—2"	5.0	4.0	5.0	6.0
	2—3"	8.0	9.0	6.0	5.0
	3—4"	2.0	2.0	2.0	2.0

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APPENDIX

2,4—D : — 2, 4—Dichlorophenoxy acetic acid amine salt selectively destroys all species of sedges and broad-leaved weeds growing in paddy, pastures, etc. at 1 fl oz in 2 gallons of water.

MCPA :— A mixture of Na and K salt of 2, methyl —4—chlorophenoxy acetic acid. Selectively destroys most species of broad-leaved weeds and sedges growing in paddy, sugarcane, pastures and lawns, at 1 fl oz.

TCA :— Sodium salt of trichloroacetic acid. Used as a selective weed killer at 5-25 lbs per acre. At 50 lbs/acre TCA acts as a total weed killer and controls Illuk, Bermuda grass and Cooch grass.

References

1. ALEXANDER, M. (1961). *Introduction to Soil Microbiology*, New York : John Wiley and Sons, Inc.
2. ALEXANDER, M. (1968). *Degradation of pesticides by soil bacteria. Ecology of soil bacteria*. Ed Gray, T.R.C., & Parkinson, D., pp. 256-259 Liverpool : University Press.
3. ALEXANDER, M. & ALEEM, M.I.M. (1961). *J. agric. Fd. Chem.* **9** : 44-47.
4. ARMSTRONG, D. E., CHESTERS, G. & HARRIS, R. F. (1967). *Proc. Soil Sci. Soc. Am.* **31** : 61-66
5. AUDUS, L. J. (1951). *Pl. Soil* **3** : 170-192.
6. AUDUS, L. J. (1952). *Nature, Lond.* **170** : 886-887.
7. AUDUS, L. J. (1960). *Microbial breakdown of herbicides in soils. Herbicides and the soil*. Ed• Woodford, F. K. & Segar, pp 1-19, Oxford : C.R. Blackwell Scientific Publications.
8. BAILEY, G. W. & WHITE, J. L. (1964). *J. agric. Fd. Chem.* **12** : 324-332.
9. BALAYANIS, P. C., SMITH, M. S. & WAIN, R. L. (1965). *Ann. Appl. Biol.* **55** : 149-157.
10. BURGER, K., MACRAE, I. C. & ALEXANDER, M. (1962). *Proc. Soil Sci. Soc. Am.* **26** : 243-246.
11. COHN, M. & MONOD, J. (1953). *Symp. III Soc. gen. Microbiol.* **3** : 132-149.
12. GROSSBARD, E. (1970). *Meded, Rijksfac Langbwet Gent.* **35** : 531-542.
13. HIRSCH, P. & ALEXANDER, M. (1960). *Can. J. Microbiol.* **4** : 241-249.
14. JENSEN, H. L. (1957). *Nature* **180** : 1416.
15. KAUFFMAN, D. D., KEARNEY, P. C. & SHEETS, T. J. (1965). *J. agric. Fd. Chem.* **13** : 238-242.
16. KAUFFMAN, D. D., KEARNEY, P. C. & SHEETS, T. J. (1965). *Science* **142** : 405-406.
17. KEARNEY, P. C., KAUFFMAN, D. D. & SHEETS, T. J. (1965). *J. agric. Fd. Chem.* **13** : 369-372.
18. LOOS, M. A. (1969). *Degradation of herbicides*. Ed. KEARNEY, P. C. & KAUFFMAN, D. D. pp 1-49 Marcel Dekker Inc.
19. NEWMAN, A. S. & THOMAS, J. R. (1949). *Proc. Soil Sci. Soc. Am.* **14** : 16-164.
20. SETHUNATHAN, N. (1973). *Soil Biol. Biochem.* **5** : 641-644.
21. SHEETS, T. J., CRAFTES, A. S. & DREVER, H. R. (1962). *J. agric. Fd. Chem.* **10** : 458-642.
22. TALBERT, H. E. & FLETCHELL, C. H. (1965). *Weeds* **13** : 46-52.
23. WILLIAMS, J. D. H. (1968). *Weeds Res.* **8** : 327-335.
24. ZAKI, M. A., TAYLOR, H. F. & WAIN, R. L. (1967). *Ann Appl. Biol.* **59** : 481-491.

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SHORT COMMUNICATION

The Binding Energy of an Electron Transferred to a Solvent from Halide Ions

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It is well known that halide ions (the best example is the iodide ion) in aqueous solution show strong absorption bands in the ultraviolet region. These bands are considered to be due to transfer of an electron from the anion to the solvent. The peak frequency of the band depends on electron affinity of the ion, the binding energy B of the electron in its excited state and other terms associated with heats of solvation and electronic polarization.[1,4] In the theory of Franck and Platzman[1] the binding energy B of the electron in its excited state is calculated on the assumption that the electron is subjected to the potential

$$V(r) = -e^2 (D_{op}^{-1} - D_s^{-1})/r$$
$$= -e^2 Z_{eff}/r, \qquad (1)$$

where D_{op}, D_s are the optical and static dielectric constants of the solvent. The expression (1) gives the potential a dipolar medium arranged round a negative ion would have at small distances.[2] It is essentially a coulomb i.e. potential with a renormalized charge,

$$eZ_{eff} = e (D_{op}^{-1} - D_s^{-1}),$$

and the binding energy of the electron is given by

$$B = -mZ_{eff}^2 \, e^4/2n^2n^2, \qquad (2)$$

where m is the electron mass and n is an integer. Franck and Platzman[1] assumed that for halides the transferred electron is in a 2S state, so that the binding energy is approximately 1eV. The binding energy in the ground state (1S state) is so high ($\sim$ 4eV) that it even exceeds the electron affinity of the halogen atom. Franck and Platzman[1] give no satisfactory reason as to why the electron should not be in the 2S excited state. The more recent theory of Stein and Treinin[4] which is partly successful in explaining the variation of peak frequency with temperature and the nature of the medium also makes the same assumption. For halides, they assume that B is given by (2) with $n = 2$. The theory completely fails if the electron is allowed to occupy the 1S state. In this work we present a more realistic calculation of B

taking into account the short distance behaviour of the potential to which the electron is subjected. It is shown that the electron could be transferred to the ground state and that binding energy in this state is not impossibly high as in the previous theories.

We assume that the dipolar molecules of the solvent are oriented around the negative ion giving rise to the potential (1). However, at short distances this macroscopic description becomes inaccurate and the effect of individual dipoles has to be taken into account. Since the electric field due to a dipole vary as $1/r^3$, only few oriented dipoles interact with the electron and the potential experienced by the electron due to this field is approximately $\mu e/r^2$, where μ is a parameter comparable to the dipole moment of a single molecule. As the positive ends of the dipoles are pointed towards the anion the above force is repulsive. The net potential seen by the electron is

$$V(r) = \mu e/r^2 - Z_{eff}e^2/r. \qquad (3)$$

V(r) is repulsive when $r < r_o = \mu/Z_{eff}e$ and becomes minimum when $r = 2r_o$, the minimum value being $V = V_o = -Z^2_{eff}/4\mu$. Setting $\mu = 1.87$ De (dipole moment of the water molecule) we obtain $r_o = 3.2$ A°, which is not unreasonable. The Schrodinger equation is exactly solvable for the potential (3) and the energy eigenvalues are given by the expression,[3]

$$E = -2mZ^2_{eff}\, e^4/n^2 \left[(2n + 1) + \{ (2l + 1)^2 + B\mu me/n^2 \}^{\frac{1}{2}} \right]^{-2} \qquad (4)$$

where n = zero or an integer and l is the orbital angular momentum quantum number. The eigenfunctions can be expressed in terms of confluent hypergeometric functions.[3] For the ground state ($n = 0$, $l = 0$), the above expression yields $B = -E \simeq .5$ eV(excited states will have much less energy). Thus our calculations show that the major difficulty of the previous theories disappear when the short distance behaviour of the force experienced by the electron transferred to the solvent is taken into account.

References

1. Franck, J., & Platzman, R. L., (1954) Z. *Phys.* **138** : 411.
2. Landau, L. D., (1933) *Sowiet Physik*, **3**: 664.
3. Landau, L. D., & Lifshitz, E. M., (1965) *Quantum Mechanics*, 2nd Edition, Pergamon Press.
4. Stein, G., & Treinin, A. (1958) *Trans. Faraday Soc.*, **54**: 338.

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SHORT COMMUNICATION

Static Electrification of Dust Particles in a Hot Tenuous Plasma

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In this paper we show that dust particles in a hot tenuous plasma of electrons and positive ions can acquire positive or negative static charges. Experimental evidence to support the theory is given. Possible astrophysical implications of the process are discussed.

We assume that dust particles (by dust particles we mean fine grains of solid matter having dimensions much greater than that of an atom or a molecule) are in thermal equilibrium with a tenuous nonrelativistic plasma at temperature T. Heated solid dust particles in the plasma will emit thermionic electrons. The number of thermionic electrons N_1 emitted per sec per unit area is given by Richardson's equation[3]

$$N_1 = Ae^{-\varphi e/kT}. \qquad (1)$$

where k = Boltzmann constant and e = electronic charge. When quantum mechanical tunneling from the surface is neglected, the constant A in the equation (1) takes the value,[3]

$$A = 4\pi mk^2T^2/h^3. \qquad (2)$$

where m is the mass of the electron and h is Planck's constant. The work function φ is few electron volts for most solid materials.[3] As positive charge accumulates on the surface of the grain, (due to electron loss) N_1 diminishes, because electrons will have to do more work to overcome the attraction due to positive charge on the particle. We assume that a dust particle is a sphere of radius r. Then the additional energy needed to remove an electron from its surface when the particle is charged is 4π sre, where s is the surface charge density measured in electronic charges on the particle. Thus the effective work function is changed to ($\varphi + 4\pi$ rse) and the equation (1) becomes,

$$N_1 = As^{1-(\varphi e + 4\pi rse)/kT}. \qquad (3)$$

At equilibrium, the rate at which the charge is lost from the dust grains due to thermionic emission must be equal to the rate at which the negative charge is deposited on the grain as a result of impact of electrons and ions in the plasma. If n = number density of electrons in the plasma = number density of positive ions, U_- = velocity of the electrons and U_+ = velocity of positive ions. The negative charge incident on the surface of the grain per sec per unit area is

$$N_2 = n/^3 (U_- — U_+) \tag{4}$$

At equilibrium $N^1 = N_2$. Thus equating expressions (3) and (4) we get

$$s = (v — \varphi)/4\pi r, \tag{5}$$

where

$$v = (kT/e) \text{ in } 3A/n (U_- — U_+). \tag{6}$$

From (5) and (6) it is seen that s is positive or negative according to as $\varphi < v$ or $\varphi > v$. However, for negative s equation (3) correctly describe electron emission only if

$$\varphi > 4\pi r/s. \tag{7}$$

When the condition (7) is not satisfied, the electron emission from a surface is not thermionic emission, but field ion emission,[1] which is governed by an expression different from (3). It follows equation (5) that for $s < O$, s satisfies the condition (7) provided $3A > n (U_- — U_+)$. Therefore the dust grains in the plasma can acquire either positive or negative charges depending on whether $(\varphi — vv)$ is positive or negative. But if $3A < n (U_- — U_+)$ the condition (7) cannot be satisfied and (5) does not give the surface charge correctly.

To make numerical estimates we consider a plasma of slightly ionized hydrogen. From the Saha ionization equation, the number of electrons per unit volume in the plasma is given by

$$n = (2\pi mkT)^{3/4} (2n_o) 1/2_h — 3/2_e — I/kT, \tag{8}$$

where n = number of unionized atoms per unit volume. The velocity of electrons in the plasma is,

$$U_- = (kT/m)^{1/2}, \tag{9}$$

and that of positive ions given by a similar expression is negligible. Hence from equations (2), (8) and (9) we obtain

$$v = (kT/e) \text{ in } [1.42 (mkT/h^2)^{3/4} n_o{}^{-1/2}] + 1/2e. \tag{10}$$

Unless the plasma is extremely dense the quantity inside the square bracket is positive and the condition $3A > n(U_- - U_+)$ holds. The Table 1 gives the values of v (volts) computed from the equation (10) for various temperatures and densities. Since the work function for most common solid materials is approximately 2 — 10 eV, it follows from the Table 1 and Equation (5), that at low temperatures and high densities dust grains in a plasma could have negative static charges. At high temperatures and low plasma densities the surface charge becomes strongly positive. At a temperature of 10^4, K the total charge on a dust grain of radius 10^{-6}cm in ionized hydrogen (ionization energy I=13.6eV) containg 10^8 atoms per cm^3 is approximately 10^{-6} e.s.u. (a positive charge approximately 10^4 times the electronic charge).

TABLE 1. Values of v computed from equation (10) for various temperatures and plasma densities.

T K	10^3			10^4			10^5		
$n_e cm^{-3}$	1	10^8	10^{18}	1	10^8	10^{18}	1	10^8	10^{18}
v (V)	8.6	8.1	7.2	26.9	20.9	12.2	222.2	162.8	76.5

As the dust particles are very massive compared to the ions in the plasma, presence of charged dust grains in a plasma cannot be demonstrated by conductivity measurements of the plasma. However, it is possible to give one simple experimental fact as evidence for the effect we have predicted. It is well known that flames have the power to neutralize charges on surfaces. A charged glass rod passed over a flame gets discharged. This may be due to the presence of ions in the flame. But the interesting thing to note is that even if the rod is held at a distance more than one foot from a Bunsen flame the rod gets discharged. The mean free path of electrons and positive ions in air is very small.[4] It is not possible for the ions in the flame to travel a distance one foot from the flame. Nevertheless, charged dust grains from the flame can travel long distances and neutralization of the charged rod is due to these particles ejected from the flame.

The effect we have described should have important astrophysical implications. The central region of the galaxy is known to contain a tenuous plasma of hydrogen and helium heavily loaded with dust.[5] Static charges on such dust grains could assist condensation in presence of electric fields. The same process might enhance condensation of matter to form protostars and planets.

References

1. FOWLER, R. H. & NORDHEIM. L., (1929) *Proc. R. Soc.* **A124**, : 694.
2. HANS, R. G., (1964) *Plasma Spectroscopy*, pp. 32-38, McGraw Hill.
3. HAUG., A. (1972) *Theoretical Solid State Physics*, pp 136-137, Pergamon Press.
4. MASSEY., H. S. W. & BURHOP, E. H. S., (1969) *Electronic and Ionic Impact Phenomena*, Vol. 1.. Oxford.
5. WICKRAMASINGHE, N. C., (1967) *Interstellar grains*, Chapman Hall.

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කුකුල් ආහාර සලාකවල ප්‍රෝටීන පරිපූරකයක් වශයෙන් පටපණු කෝෂ පිලව් (*Bombyx mori L.*) භාවිතාකිරීම

ඩිජේසිංහ. ඇම්. ඇස්. සහ රාජගුරු, ඒ. එස්. බී.

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මස් කුකුල් පැටව්, වැඩුණ මස් කුකුළන් හා බිත්තර දමන කිකිළියන්ගේ ක්‍රියාකාරිත්වය කෙරෙහි දේශීය කුකුල් කෑම වෙනුවට පටපණු කෝෂ පිලව් (SWP) භාවිතයට ගත හැකි විවිධ මට්ටම්වල පැවැත්ම ගැන දැන ගැනීමට පරීක්ෂණයක් පවත්වන ලදි. දේශීය වශයෙන් භාවිතයට ගන්නා කුකුල් ආහාර සලාක සඳහා පටපණු කෝෂ පිලව් (SWP) ඉතා සාර්ථක ලෙස ප්‍රයෝජනයට ගත හැකි බව මෙම පරීක්ෂණයේ ප්‍රතිඵලවලින් පෙනී ගියේය. කුකුල් පැටවුන්ට පටපණු කෝෂ පිලව් (SWP) ආහාර සඳහා දීමෙන් ඔවුන් ඉතා ශීඝ්‍රයෙන් වැඩෙන බවට එක්තරා සාධකයක්ද සොයාගත හැකි විය. බිත්තර දමන කිකිළියන්ට දෙන ආහාර වේලට පටපණු කෝෂ පිලව් (SWP) බිත්තර රහිත අවස්ථාවේදී එක් කිරීම හේතු කොටගෙන රකුම් ශක්තියේ සහ කුකුල් පැටවුන්ගේ බරෙහිදි වර්ධනයක් ඇතිවුවා පමණක් නොව එම සතුන්ගේ ප්‍රජනක ක්‍රියාකාරිත්වයද වැඩි දියුණු වූ බව සොයා ගන්නා ලදි. එම කුකුල් පැටවුන්ගෙන් වැඩි දෙනා ගැහැණු සතුන් වූ හෙයින් ලිංගික අනුජාතයේද වැඩි වාසිදායක වෙනසක් ඇති බව නිරීක්ෂණ වලින් දැනගත හැකි විය.

ශ්‍රී ලංකාවේ මැදරට ඇතිකරන යුරෝපීය ගවයන්ගේ තණකොළ කෑමේ පුරුද්ද ගැන නිරීක්ෂණ කීපයක්

කාසිවාමුරා, පුම්රෝ සහ ජයසූරිය, එම්. සී. එන්.

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ශ්‍රී ලංකාවේ මැදරට ඇතිකරන විදේශීය කිරි හරකුන්ගේ පුරුදු ගැන අවබෝධයක් ලබාගැනීමට දෙවැදරුම් අධ්‍යයනයක්, එනම්: ගවමඩු අධ්‍යයනයක් සහ ක්ෂේත්‍ර අධ්‍යයනයක්ද පවත්වන ලදි. ශ්‍රී ලංකා විශ්ව විද්‍යාලයේ පේරාදේණිය මණ්ඩපයේ සත්ව පාලන දෙපාර්තමේන්තුවේ පරීක්ෂණ කිරිපට්ටි ඒකකය තුළදී ප්‍රෙසියන්, ඇෂයර් සහ ජර්සි වර්ගවලට අයත් කිරි එළදෙනුන් හය දෙනෙකු (එක් වර්ගයකින් දෙදෙනා බැගින්) ගෙන ඔවුන්ගේ පැවතුම් රටා ගැන නිරීක්ෂණ කීපයක් පවත්වන ලදි. ගව මඩුවේදී කරන ලද ශූන්‍ය උලා කෑමේ සහ සිවිවනියේ තණ කොළ උලා කෑමේ ප්‍රමාණය පිළිවෙලින් පැය 8.80 සහ පැය 9.55 ද විය. තණ උලා කෑමේ සහ රෝමන්ථනය කිරීමේ අනුපාතය (G/R) පිළිවෙලින් 1.47 සහ 1.34 ක් විය. සෞම්‍ය කලාපීය ප්‍රදේශවලින් ලැබී ඇති වර්තා හා සසඳන විට මෙම ප්‍රමාණ ඊට වඩා වැඩිවේ. සමහර විට සෞම්‍ය කලාපීය සහ දේශීය සත්ව ආහාරවල නිසර්ග සිද්ධ වෙනස්කම් මීට හේතුවන්නට ඇත. මෙම අධ්‍යයන දෙක මඟින් සොයා ගන්නා ලද කරුණු අනුව දවල් කාලයේදී තණ උලාකෑම වැඩි බව සොයාගත හැකි විය. කෙසේ වුවද මේ දෙවැදරුම් තණ කෑවීමේ ක්‍රම දෙක සම-

බන්ධයෙන් බලන විට රාත්‍රියේ සහ දවල් කාලයේදී පැයක කාලයක් තුලදී ආහාර ගැනීමේ උඩිව අවස්ථාවක් පෙනෙන්නට තිබිණි. මෙම නිරීක්ෂණයන්ගේ ප්‍රතිඵල අනුව, මැදරට විදේශීය කිරි හරකුන්ට දවල් කාලයේදී උපරිම තණ උලා කෑමේ අවස්ථාවක් යලසාදීම අවශ්‍ය බව පෙනී ගියේය. ශුන්‍ය තණ උලාකෑම අනුගමනය කරන්නේ නම්, වැඩි වශයෙන් ආහාර ගන්නා කාලවකවානුවලට ගැලපෙන සේ තණකොළ තුන්වරක් දීමට වගබලා ගත යුතුය. ප.ව.6.00 සිට පෙ.ව. 6.00 දක්වා ගව මඩුවේදී හෝ පිටිටනියේදී තණුලා කෑමේ අනුපාතය 30% ක් පමණ වන නිසා, රාත්‍රි කාලයේ දී හරකුන් කොටුකර තබා සෑහෙන ප්‍රමාණයක තණ උලාකෑමට හෝ කැපූ තණකොළ දීමට කටයුතු කිරීමෙන් උපරිම කිරි නිෂ්පාදනයක් ලබාගත හැකිය. ගවපාලනයේදී එසේ පියවර ගන්නා මෙන් මෙයින් උපදෙස් දෙනු ලැබේ.

ශ්‍රී ලංකාවේ වාණිජ පදනමක් යටතේ කජු මද පිරිසැකසුම් කිරීම සහ කජු ලෙලි සාරය (CNSL) නිෂ්පාදනය කිරීම පිළිබඳ ප්‍රාරම්භික අධ්‍යාපනයක්

රාජපක්ෂ, ආර්. ඒ., ගුණතිලක, පී. ඒ. සහ විජේකෝන්, කේ. බී.

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වර්තමාන ශ්‍රී ලංකාවේ කජුමද පිරිසැකසුම් කරන්නේ ගෘහ කර්මාන්තයක් වශයෙන් පාරම්පරික ක්‍රම අනුගමනය කිරීමෙන්ය. 'සම්පූර්ණත්වය' හා පාට ගැන සලකන කල්හි එසේ පිළියෙල කරනු ලබන කජුමදවල තත්වයේ සෑහෙන වෙනස්කම් දක්නට ලැබේ. තවද වාණිජ අංශවල බොහෝ දේවල් නිෂ්පාදනය සඳහා ප්‍රයෝජනයට ගත හැකි කජු ලෙල්ලේ ඇති රසායනික ද්‍රව්‍යයක් වන 'පීනෝල්': පාරම්පරික ක්‍රම මගින් ලබාගන්නා සිරිතක් නැත. නුදුරු වර්ෂවලදී ලංකාවේ කජු නිෂ්පාදනය පස් ගුණයකින් වැඩිවේ යයි බලාපොරොත්තු වනු ලැබේ. එමනියා කජුමද පිරිසැකසුම් කිරීම සහ කජු ලෙල්ලේ සාරය වාණිජ පදනමක් යටතේ නිෂ්පාදනය කිරීම පිළිබඳව අධ්‍යයනයක් ආරම්භ කොට ඇත. 'උණු-තෙල්-ස්නාහක' ක්‍රමය උපයෝගී කරගෙන කජුමද සතුටුදායක ලෙස පිරිසැකසුම් කළ හැකි බවද සෙන්ටිග්‍රෙඩ් අංශක 185 සිට 190 දක්වා පිරිසැකසුම් උෂ්ණත්වයකදී කජු ලෙල්ලේ සාරය උකහා ගත හැකි බවද මෙම පර්යේෂණ මගින් ස්ථාපිත කොට ඇත. පිරිසැකසුම් කළයුතු කාලය මිනිත්තු 1½ සිට 4 දක්වා විය හැක.

වැල්දෙඩම් සහ දර දඹල ඇට ගමා විකිරණයට දක්වන විකිරණශීල සංවේදිතාව

සේනානායක, ඩබ්. ඩී. ඒ. සහ පෙරේරා, එල්. ඒ.

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දර දඹල සහ වැල්දෙඩම් ඇට පිළිවෙලින් 10–70kr සහ 15–25kr ගමා විකිරණ ප්‍රමාණයන්ට භාජනය කරනු ලැබීමෙන් පසුව පැල තවානක තට්ටුවල රෝපණය වීමට සලස්වන ලදී. 30–40kr ප්‍රමාණයේදී LD_{50} ක් පැවතුණ දර දඹල' 17.5–20kr ප්‍රමාණයේදී LD_{50} ක් පැවතුණ වැල්දෙඩම් සමඟ සංසන්දනය කිරීමේදී ගමා විකිරණයට වඩා ඔරොත්තු දෙන ශක්තියක් ඇති බව පෙනී ගියේය. පිළිවෙලින් 40kr සහ 20kr වලට වැඩි විකිරණය දඹලවලට සහ වැල්-දෙඩම්වලට හානිකර බවද පෙනිගියේය. පැලවුණ ඕයලුම් දර දඹල පැල විකිරණයට පාත්‍රකිරීම වැඩිවීමෙන් පසුවද නොමැරී තිබුණ අතර වැල්දෙඩම් පැල රාශියක් විකිරණයට පාත්‍ර කිරීම වැඩි වෙනවාත් සමඟම මැරී ගියේය.

විවිධ මාදිලිවලට අයත් සිට්‍රනෙල්ලා තෙල්වල සංයුතියේ වෙනස්කම්

ඉරුදයදස්, ඊ. ඊ., හේරත්, එච්. එම්. ඩබ්ලිව්., විජේසේකර, ආර්. ඕ. බී. සහ ජයවර්ධන, ඒ. එල්.

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ශ්‍රී ලංකාවේ වෙළඳාම සඳහා නිෂ්පාදනය කරනු ලබන සිට්‍රනෙල්ලා (පැහිරි) තෙල් වැඩි වශයෙන්ම ලබාගන්නේ 'ලේනබටු' තෘණ පැලැටියෙන්ය. සිට්‍රනෙල්ලා වගාවන්හි ලේනබටු සහ මහපැහිරි යන දෙවර්ගයටම අයත් මිශ්‍ර වගාවක් දක්නට ඇත. මේ වර්ග දෙක පරීක්ෂා කිරීමෙන් පසුව පැහිරි මාදිලි එකොළහක් යොයාගත හැකි විය. මෙම මාදිලි ප්‍රචාරණය පිළිබඳව සහ මෙවායින් ලබාගන්නා වාෂ්පශීලී තෙල පිළිබඳව වායු-ද්‍රව-වර්ණ ලේඛ ක්‍රමය උපයෝගී කර ගැනීමෙන් කරන ලද විමර්ශනවලින් ඒවායෙහි අන්තර්ගත තිස් එකක් වූ රසායනික සංඝටකවල වෙනස්කම් පවතින බව සොයා ගත හැකිවිය. මේ පැහිරි ගස්වල ශාක කොටස් වලින් මෙන්ම මල් හටගන්නා කොටස්වලින්ද වාෂ්පශීලී තෙල් ලබාගත හැකිය. එකම ගසේ කොළ තෙල්වල හා මල් තෙල්වලද වෙනස්කම් තිබිණි. එකම ගසේ විවිධ මාදිලිවලද විවිධ රසායනික ලක්ෂණ දක්නට ලැබිණි. එක ගණයකට අයත් සංඝටන නිෂ්පාදනය අනික් ගණයට අයත් ඒවාට වඩා වැඩිවීමට බලපාන සාධක කවරේදැයි නිගමනය කිරීමට සහසම්බන්ධතා පරීක්ෂණවල ප්‍රතිඵලවලින් හැකිවිය. මෙතෙක් වාර්තාකොට ඇති තෙල්වල රසායනික සංයුතියේ විචල්‍යතාව ඒ ඒ මාදිලිවල ප්‍රවේණි විෂමතාවන්ට අනුකූලව පවතින බවද නිරීක්ෂණයට කොට ඇත.

පැලැටිනාශක වර්ග කිපයක අවශිෂ්ට ධූලකත්වය
(i) 2, 4–D, MCPA සහ TCA

වීරරත්න, සී. එස්.

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කාණ්ඩ 4 කට අයත් පොදුවේ දක්නට ලැබෙන පස් වර්ගවල – එනම් රතු දුඹුරු පස, රතු දුඹුරු ලැටසෝලික් (බොරළු සහ කබොක්) පස, නොමේරූ දුඹුරු ලෝම් පස සහ ඌන-හියුමස් ග්ලි පස යන පස් වර්ගවල 2, 4–ඩෙක්ලෝරෝපිනොක්සි ඇසිටික් ඇසිඩ්, 2–මෙතිල්–4–ක්ලෝරොපිනොක්සි ඇසිටික් ඇසිඩ් සහ ට්‍රෙක්ලොරෝ ඇසිටික් ඇසිඩ යන අම්ලයන්හි අවශිෂ්ට ධූලකත්වය පරීක්ෂාවකට භාජනය කරන ලදී. සති 13 ක කාලයක් තිස්සේ එම රසායනික අම්ල අඩංගු සංයුක්තයන් මිශ්‍ර කරන ලද පස් වර්ග, අවගාහන සහ අනාවගාහන තත්වයන් යටතේ ආසිනකරණය කිරීමෙන් මෙම පරීක්ෂණය පවත්වන ලදී. ජෛව-අර්සණ පරීක්ෂා මගින් අවශිෂ්ට ධූලකත්වය මනින ලදී. අනාවගාහන තත්වය යටතේ අධ්‍යයනය කරන ලද සියලුම පාංශු සංයුක්තවල ප්‍රතිඵලවලින් පෙනී යන්නේ ඌන හියුමස් ග්ලි පස්වල (LHG) වෙන පස් වර්ගවලට වඩා ආසිනකරණ කාලය තුළදී අවශිෂ්ට ධූලකත්වය ඉතා වේගයෙන් අඩුවන්නට පටන් ගන්නා බවයි. අධ්‍යයනය කරන ලද පාංශු සංයුක්තවල PCA අවශිෂ්ට ධූලකත්වයට වඩා වැඩි වේගයකින් 2, 4–D සහ MCPH වල අවශිෂ්ට ධූලකත්වය අඩුවී යන බව පෙනුණි. අවගාහන තත්වය යටතේ, TCA හැරුණු විට, පරීක්ෂාවට භාජනය කරන ලද සෙසු සංයුක්තවල අවශිෂ්ට ධූලකත්වය, අනාවගාහන තත්වයන් යටතේ කරන ලද පරීක්ෂණ හා සසඳා බලන කල්හි ඉතා අඩු අනුපාතයකින් අඩුවී ගියේය.

අවගාහන සහ අනාවගාහන තත්වයන් යටතේ, පිඩනාපකය මගින් බීජාහරණය කරන ලද පස් යොදු කරන ලද අවගිෂ්ට ධූලකත්ව පරීක්ෂණවලින් හෙළිවූයේ TCA හැරුණු විට පරීක්ෂාවට භාජනය කරන ලද අනික් සංයුක්තවල ධූලකත්වය අඩුවීමට හේතු වන්නේ ක්ෂුද්‍ර ජීවීන්ගේ ක්‍රියාකාරිත්වය බවයි. එහෙත් TCA සංයුක්තවල ක්ෂුද්‍ර ජීවීන්ගේ ක්‍රියාකාරිත්වය සහ රසායනික වියෝජනය යන කරුණු දෙකම නිසා ධූලකත්වය අඩුවන බව පෙනුණි. මෙම සංයුක්ත යොදු කලින් ආසීනකරණයට පාත්‍ර කරන ලද පස් වර්ගවල අවගිෂ්ට ධූලකත්වය ඉතා වේගයෙන් අඩුවන බව පරීක්ෂණයට භාජනය කළ සංයුක්තවලින් පෙනී ගියේය. ආසීනකරණ පරීක්ෂණ මගින් සොයාගත් කරුණු අනාවගාහන තත්වය යටතේ කරන ලද ක්ෂේත්‍ර අධ්‍යයනවලින් සනාථ විය. මෙම පැලැටිනාශක, පස් සමඟ අධිශෝපණය වන ප්‍රමාණය පරීක්ෂාවට භාජනය කරන ලද්දේ ක්ෂරණ පරීක්ෂණ මඟිනි්ය. පරීක්ෂණයට භාජනය කරන ලද සංයුක්තවලින් දැනගත හැකි වූයේ පස්වල පළමුවන අඟල් 3 ක ප්‍රදේශයට එම සංයුක්ත අධිශෝෂණය වන බවය. O. M ප්‍රමාණය සාපේක්ෂක වශයෙන් වැඩිවූ පවතින LHG පස්වල අධිශෝෂණය පසේ මතුපිට තරවූවේ (අඟල් 1–2 දක්වා) සිදුවිය.

හේලයිඩ අයනයෙන් ද්‍රාවකයකට සංක්‍රාමණය වූ ඉලෙක්ට්‍රෝනයක බන්ධක ශක්තිය

තෙන්නකෝන්, කේ. සහ විජේනායක, ආර්. එච්.

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හේලයිඩ් අයනයෙන් ද්‍රාවකයකට සංක්‍රාමණය වූ ඉලෙක්ට්‍රෝනයක බන්ධක ශක්තිය විද්‍යුත් ස්ථිතික විභවයට යටත් වූ ඒක ධ්‍රැවීය සහ ද්වි ධ්‍රැවීය අවයවයන් සැලකිල්ලට ගෙන ගණනය කොට දැක්වේය. කලින් ඉදිරිපත් කරන ලද සිද්ධාන්තවල දක්වා ඇති පරිදි භූමිගත ශක්තිය ඉතා අධිකව නොපවතින බවද මෙහි පැහැදිලි කොට ඇත්තේය.

උණු තුනී ප්ලාස්මාවක ඇති ධූලි අංශුන්ගේ ස්ථිතික විද්‍යුතනය

තෙන්නකෝන්, කේ.

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උණු තුනී ප්ලාස්මාවක ඇති ධූලි අංශුවලට ධන හෝ සෘණ ස්ථිතික විද්‍යුත් ආරෝපණ ලබාගැනීමේ හැකියාව ඇති බව දක්වා ඇත.

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இந்த இதழில் கட்டுரைகளின் சுருக்கங்கள்

பண்ணைப் பற்வைத் நிவனங்களின் சுறைநிரப்புப் புரதமூலமாகப் பட்டுப்பூச்சிக் கூட்டு புழுக்களை (*Bombyx mori L*) உபயோகித்தல்

விஜேசிங்கா, எம். எஸ்., ராஜகுரு, ஏ. எஸ். பீ.

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விடலைக் கோழிக்குஞ்சுகள், வளர்ந்த விடலைக் கோழிகள், முட்டையிடும் கோழிகள் ஆகிய கோழிவகைகளின் வளர்ச்சி இயக்கம் மீது உள்ளூர் மீன் நீவனங்களுக்குப் பதிலாகப் பட்டுப்பூச்சிக் கூட்டுப் புழுக்களை உபயோகிக்கக் கூடிய முறைகளின் சாத்தியக்கூறுகளைப் பற்றி அறிவதற்கு ஓர் ஆய்வு மேற்கொள்ளப்பட்டது. உள்ளூரில் பயன்படுத்தப்பட்டுவரும் கோழிகளுக்கான மீன்நீவனங்களுக்குப் பதிலாகப் பட்டுப்பூச்சிக் கூட்டுப் புழுக்களை (SWP) வெற்றிகரமாக உபயோகிக்கலாமென்பதை மேற்படி சோதனையின் பெறுபேறுகள் காட்டின. கோழிக்குஞ்சுகளுக்குப் பட்டுப்பூச்சிக் கூட்டுப் புழுக்களை (SWP) உணவாக அளிப்பதன் மூலம் அவைகள் வெகு சீக்கிரம் வளர்கின்றனவென்பதைக் காட்டும் ஒரு காரணியும் கண்டுபிடிக்கப்பட்டது. முட்டையிடும் கோழிகளுக்குக் கொடுக்கப்பட்டுவரும் உணவுப் பங்கீட்டுக்குப் பட்டுப்பூச்சிக் கூட்டுப் புழுக்களை (SWP) அடை காக்கும் பருவத்திற் சேர்ப்பதனால் குஞ்சு பொரிக்குமாற்றல் அதிகரித்ததோடு பொரிக்கப்பட்ட குஞ்சுகளின் எடையும் அதிகரித்தது. இதனால் அப்பறவைகளின் இனப் பெருக்கச் சக்தியும் விருத்தியாகிறதென்பது கண்டுபிடிக்கப்பட்டது. அக் குஞ்சுகளின் பெரும்பான்மையானவை பெண்பறவைகளாகவிருந்தபடியால் அவற்றின் பால்சார் வீதத்திலும் பயன்மிக்க மாற்றம் ஏற்பட்டிருப்பதும் அந்த அவதானிப்புகளால் புலனுகியது.

இலங்கையின் மத்திய பகுதியில் வளர்க்கப்படும் ஐரோப்பிய இன மாடுகளின் புல மேய்ச்சல் பழக்கம் பற்றிய சில அவதானிப்புகள்

காசிவாமுரு, புமிரே., ஜயசூரிய, எம். சி. என்.

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இலங்கையின் மத்திய பிரதேசத்தில் வளர்க்கப்படும் சீமைப் பால்மாடுகளின் பழக்கங்களைப் பற்றி அறிவதற்கு இருவகையான ஆய்வுகள்—அதாவது மாட்டுத் தொழுவச் சோதனையொன்றும் களநிலைச் சோதனையொன்றும் நடாத்தப்பட்டது. இலங்கைப் பல்கலைக்கழகத்தின் பேராதனை வளாகத்து விலங்கு வேளாண்மைப் பகுதியின் பரிசோதனைப் பாற்பண்ணைப் பிரிவில் வைத்து, பிறேசியன், அஷயர், ஜர்சி ஆகிய இனங்களைச் சேர்ந்த ஆறு பால் மாடுகளின் (ஒவ்வொரு இனத்தினின்றும் இரண்டு மாடுகள் வீதம்) பழக்க முறைகளைப் பற்றிய ஓர் ஆய்வு மேற்கொள்ளப்பட்டது. மாட்டுத் தொழு

வத்தில் நிகழும் அடிநிலமேய்ச்சல் வீதத்தினதும் புல்நிலத்தில் நிகழும் களநிலை மேச்சல் வீதத்தினதும் காலம் முறையாக 8.80 மணியாகவுதம் 9.55 மணியாகவும் இருந்தது. புல்மேய்ச்சல் மற்றும் அசைபோடுதல் (G/R) என்பவற்றின் வீதம் முறையே, 1.47 ஆகவும் 1.34 ஆகவும் இருந்தது. நடுவெப்பநிலைப் பிரதேசங்களிலிருந்து கிடைத்துள்ள அறிக்கைகளோடு ஒப்புநோக்குமிடத்து இவ்வீதம் அதிகமாகவே இருப்பதைக் காணலாம். நடுவெப்பமுள்ள பிரதேசங்களிலும் உள்ளூரிலும் கிடைக்கும் விலங்குத் தீவனங்களிலுள்ள இயல்பான வித்தியாசங்கள் இதற்குக் காரணமாய் இருக்கலாம். இவ்விரண்டு ஆய்வுகளின் மூலம் கண்டுபிடிக்கப்பட்ட தரவுகளின்படி பகல் நேர மேய்ச்சல் அதிகம் என்பது கண்டறியப்பட்டுள்ளது. எவ்வாறுயினும் இவ்விருவகைப்பட்ட மேயவிடல் முறைகளும் உற்று நோக்குமிடத்து இராப்பொழுதிலும் பகற்பொழுதிலுமாக உணவு உட்கொள்ளும் உச்சநிலையாக ஒரு மணி நேரகாலம் இருப்பது புலனாயிற்று. இந்த அவதானிப்புகளின்படி, மத்தியப் பிரதேச சீமைப் பால்மாடுகளுக்குப் பகற்பொழுதில் ஆகக்கூடிய அளவு புல்மேயவிடும் வசதிகள் இருப்பது அவசியமென்பதும் புலனாகியது. அடிநிலை மேய்ச்சல் முறை பின்பற்றப்படின் மிகக் கூடிய அளவு உணவு உட்கொள்ளும் நேரகாலங்களுக்கேற்பப் புல்லை மூன்று தடவைகள் கொடுப்பதற்கு ஆவன செய்தல் வேண்டும். பி. ப. 6.00 மணிமுதல் மு. ப. 6.00 மணி வரை மாட்டுத் தொழுவதத்தில் அல்லது புற்றரையில் புல்மேயும் வீதம் 30% ஆகவுள்ள படியால் இராப்பொழுதில் வேலியிடப்பட்ட பகுதியில் மாடுகளை மேய விடுவதன் மூலமாகவோ தொழுவத்தில் வெட்டிய புல்லைத் தருவதன் மூலமாகவோ பால் உற்பத்தியை அதிகரிக்கலாம். விலங்கு வேளாண்மை செய்வோர் இதன்வண்ணம் நடவடிக்கை எடுக்க வேண்டப்படுவர்.

இலங்கையில் வர்த்தக அடிப்படையில் முந்திரிக்கொட்டைச் சிர்முறை செய்தலும் முந்திரிக்கொட்டைப் புறணி நீர்ம (C.N.S.L.) உற்பத்தியும் பற்றிய தொடக்கநிலை ஆய்வொன்று

ராஜபக்ச, ஆர். ஏ., குணதிலக்க, பீ. ஏ., விஜேகோன், கே. பீ.

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இன்று இலங்கையில் முந்திரிக்கொட்டைச் சீர்முறைப்படுத்தலானது ஒரு குடிசைக் கைத்தொழிலாகப் பாரம்பரிய முறைகளைத் தழுவியே செய்யப்பட்டுவருகிறது. ''முழுமையை'' யும் நிறத்தையும் பொறுத்தவரை அவ்வாறு தயாரிக்கப்படும் முந்திரிப்பருப்புகளின் பண்பியல்பின் பல வித்தியாசங்கள் உள்ளன. மேலும் வர்த்தக நிலையங்களின் பலபொருள் ஆக்கத்திற்குப் பயன்படக்கூடிய முந்திரிக்கொட்டைப் புறணியிலுள்ள ஓர் இரசாயனப் பதார்த்தமான ''பீனோல்'' மரபுவழிவந்த முறைகளைக் கொண்டு பெறத்தக்க வசதிகள் இல்லை. வருங்காலத்தில் இலங்கையின் முந்திரிகொட்டை உற்பத்தியானது ஐந்து மடங்கு அதிகரிக்கலாமென நம்பப்படு

கிறது. எனவே முந்திரிக்கொட்டைச் சீர்முறை செய்தல் பற்றியும் வர்த்தக அடிப்படையில் முந்திரிக் கொட்டைப் புறணி நீர்மத்தை உற்பத்தி செய்தல் பற்றியுமான ஓர் ஆய்வு மேற்கொள்ளப்பட்டுள்ளது. ''வெப்ப-எண்ணெய்த்-தொட்டி'' முறையினைப் பயன்படுத்தி முந்திரிக் கொட்டைகளை நல்ல முறையில் சீர்முறைப்படுத்துவதற்கும் சென்றிகிரேட் 185- முதல் 190 வரையான வெப்பநிலையில் முந்திரிக்கொட்டைப்புறணியின் நீர்மத்தைப் பிரித்தெடுப்பதற்குமான சாத்தியக்கூறுகள் இப்பரிசோதனைகளின் மூலம் நிலைநாட்டப்பட்டுள்ளன. சீர்முறைப்படுத்தப்படவேண்டிய நேரம் 1½ நிமிடம் முதல் 4 நிமிடம்வரை இருக்கலாமென்பதும் கண்டுபிடிக்கப்பட்டுள்ளது.

செட்டை அவரை மற்றும் கொடித்தோடைகள் காமாகதிரியக்கத்திற்குக் காட்டும்கதிர் உணர்த்திறன்

சேனநாயக்கா, வை. டீ. ஏ., பெரேரா, எஸ். ஏ.

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செட்டை அவரை மற்றும் கொடித்தோடைக் கொட்டைகள் முறையே, *10* — *70* kr, *15* — *25* kr காமா கதிரியக்க அளவுகளுக்கு உள்ளாக்கப்பட்டதன் பின்னர் ஒரு தாவர இல்லத்தின் தட்டைநிலங்களில் முளைக்கவிடப்பட்டன. *30* — *40* kr மட்டத்தில் LD_{50} நிலை காணப்பட்ட செட்டை அவரையை *17.5* kr — *20* kr மட்டத்தில் LD_{50} நிலை காணப்பட்ட கொடித்தோடையோடு ஒப்புநோக்கியபோது செட்டை அவரையில் காமா கதிரியக்கத்தாற் பாதிக்கப்படாது நிலைக்கக்கூடிய சக்தி இருக்கிறது என்பது கண்டறியப்பட்டது. முறையே *40* kr *20* kr நிலைகளைத் தாண்டிய கதிரியக்கம் செட்டை அவரைகளுக்கும் கொடித்தோடைகளுக்கும் தீங்குவிளைவிக்குமென்பதும் புலனுகியது. முளைத்த செட்டை அவரைக் கன்றுகள் எல்லாம் கதிரியக்கத்திற்கு உள்ளாக்கப்படுதலை அதிகரித்த பின்னரும் இறந்து போகாமல் இருந்ததோடு கொடித் தோடைக் கன்றுகள் பல கதிரியக்கச் சக்தி அதிகரிக்கப்பட்ட உடனே பட்டுப்போயின.

பல்வகைப்பட்ட சிற்றனெல்லாப் புல்லினங்களின் எண்ணெயமைப்பின் மாறல்நிலைகள்

இருதயதாஸ், ஈ. ஈ., ஹேரத், எம். எம். டபிள்யு., வஜேசேகர, ஆர். ஓ. பீ. ஜயவர்தன, ஏ. எஸ்.

J. Natn. Sci. Coun. Sri Lanka 1977 **5**(2) :

இலங்கையில் விற்பனைக்காக உற்பத்தியாக்கப்படும் சிற்றனெல்லா (காவட்டம்புல்) எண்ணெய் பெரும்பாலும் ''லேனபட்டு'' எனப்படும் புல்லிருந்து பெறப்படுகின்றது. சிற்றனெல்லாத் தோட்டங்களில் ''லேனபட்டு'' மற்றும் ''மஹாபெங்கிரி'' என்னும் இரண்டு வகைகளும் உளவென்பது உண்மையாகும். இவ்விரு வினங்களைப் பரிசோதனை செய்த பின்னர் சிற்றனெல்லா வகைகள் பதினொன்று கண்டறியப்பட்டன. இவ்வினங்களின்

இனப்பெருக்கம் பற்றியும் இவைகளாற் பெறப்படும் ஆவியாகும் தைலங் களைப் பற்றியும் வாயு-திரவ-நிறப்பதிவு முறையின்படி செய்யப்பட்ட சோதனைகளின் மூலம் அவற்றில், ஒவ்வொன்றுக்கும் வேறுபட்ட பண்புதலன் கொண்ட முப்பத்தொரு இரசாயனக்கூறுகள் இருப்பதைக் கண்டோம். இக்காவட்டம்புல்லின் பதியப்பகுதிகளிலிருந்தும் பூக்கும் பகுதிகளிலிருந்தும் ஆவியாகும் தைலங்களை எடுக்கலாம் என்பது கண்டறியப்பட்டது. ஒரே மரத்தின் இலை எண்ணெயிலும் பூவெண்ணெயிலும் வித்தியாசங்கள்காணப் பட்டன. ஒரே மரத்திற்குரிய பலவினங்களில் பல இரசாயனப் பண்பு களும் இருந்தன. ஒரு தொகுதிக்குரிய கூறுகளின்உற்பத்தி, மற்ற தொகுதிக் குரியவற்றை விட அதிகரிப்பதற்கு ஏதுவாகிய காரணிகள் எவையென துணிந்து கூறுவதற்கு இவ்வைப் பரிசோதனைகளின் மூலம் சாத்தியமாயிற்று. இதுவரை அறிக்கையிடப் பெற்றுள்ள எண்ணெய்களின் இரசாயன வமைப்பின் மாறல்நிலையானது அந்தந்த இனங்களின் பிறப்புரிமைசார். வேறுபாடுகளுக் கிணங்கியே உள்ளதென்பதும் அவதானிக்கப்பட்டுள்ளது.

பூண்டுக்கொல்லிகள் சிலவற்றின் மீதியாகும் நச்சுத்தன்மை
(1) 2, 4— D, MCPA உம் TCA உம்

விரசத்தன சி. எஸ்.

J. Natn. Sci. Coun. Sri Lanka 1977 **5**(2) :

நான்கு தொகுதிகளைச் சேர்ந்த எங்கும் காணப்படுகின்ற மண்வகைகள்— அவையாவன செங் கபிளலநிற மண், செங்கபிலநிற செம்பூராங்கல் மண், முதிராக் கபிலநிற பதமண், தாழ்-மக்கல் மண்—ஆகிய மண்வகைகளில் 2, 4- டைக்ரு ளோபீனெட்சி அசற்றிக் அசிட், 2 - மெதயில் -4 குளோரோ பீனெட்சி அசற்றிக் அசிட், திரைக்குளோரோ அசற்றிக் அசிட் ஆகிய அமிலங்களின் மீதியாகும் நச்சுத்தன்மையானது ஓர் ஆய்வுக்கு உட்படுத்தப் பட்டது. 13 வார காலப்பகுதியில் மேற்சொல்லிய இரசாயனவமிலங்கள் அடங்கிய சேர்வைகள் கலக்கப்பட்ட மண்வகைகள் அமிழ்நிலை மற்றும் அமிழாநிலைகளின் கீழ் அடைவைப்பதன் மூலம் இப்பரிசோதனை நடாத்தப் பட்டது. உயிரினமுறைப் பரீட்சைகளின் மூலம் மீதியாகும் நச்சுத்தன்மை அளவிடப்பட்டது. LHG மண்ணில் (Low-humic gley) ஏனைய மண்களை விட அடைவைத்தல் காலத்தில் மீதியாகும் நச்சுத்தன்மை மிகுந்த வேகத் தோடு குறைந்து செல்கின்றதென்பது அமிழாநிலையின் கீழ் ஆராயப்பட்ட மண்வகைச் சேர்வைகள் யாவற்றினதும் பெறுபேறுகளால் கண்டறியப்பட் டது. ஆயப்பட்ட மண்சேர்வைகளிலுள்ள PCA யின் மீதியாகும் நச்சுத்தன் மையைவிடக்கூடிய வேகத்தில் 2,4—D வினதும் MCPA வினதும் மீதியாகும் நச்சுத்தன்மை குறைந்து செல்வது காணப்பட்டது. அமிழ்நிலையின் கீழ். TCA பூண்டுக் கொல்லியைத்தவிர, ஆய்வுக்குட்படுத்தப்பட்ட ஏனைய சேர்வைகளின் மீதியாகும் நச்சுத்தன்மை அமிழாநிலையின்கீழ் செய்யப் பெற்ற ஆய்வுகளோடு ஒப்புநோக்குமிடத்து மிகவும் மந்தமாகக் குறைந்து செல்லுமென்பது புலனாகியது.

அமிழ் நிலை மற்றும் அமிழாநிலைகளின் கீழ் தற்சாவியமுறையில் கிருமியழிக்கப்பட்ட மண்வகைகளை இட்டுச் செய்யப்பட்ட மீதியாகும் நச்சுத்தன்மைப்பரீட்சைகளின்படி TCA வையத்தவிர, ஆய்வுக்குட்படுத்தப்பட்ட ஏனைய சேர்வைகளின் நச்சுத்தன்மை குறைந்து செல்வதற்கு நுண்ணுயிரிகளின் தொழிற்பாடு காரணமாகிறதுதென்பது புலனுகியது. ஆயினும் TCA சேர்வைகளிலோ நுண்ணுயிரிகளின் தொழிற்பாடு, இரசாயனப் பிரிகை ஆகிய இரு காரணங்களும் நச்சுத்தன்மையை அழிப்பதற்கு ஏதுவாகின்றன எனலாம். இச் சேர்வைகளைக் கொண்டு முன்னதாகவே அடைவைத்தற்கு உள்ளாக்கப்பட்ட மண்வகைகளின் மீதியாகும் நச்சுத்தன்மை மிகுந்த வேகத்திற் குறைந்து செல்கின்றதென்பதை ஆய்வுட்குட்பட்ட சேர்வைகள் காட்டிவிட்டன. அடைவைத்தற் பரீட்சைகளின் மூலம் சேகரிக்கப்பட்ட தரவுகள் அமிழாநிலையின் கீழ் மேற்கொள்ளப்பட்ட களநிலை ஆய்வுகளால் நிலைநாட்டப்பட்டன. நீர்முறையிப்புப் பரீட்சைகளின் மூலம் இப்பூண்டுக்கொல்லிகளின் மண்ணோடு புறத்துறிஞ்சலாற்றலானது அளவிடப்பட்டது. மண்ணின் மேற் பறப்பின் முதல் 3 அங்குல ஆழம் வரை இச் சேர்வைகள் மண்ணுக்குள் உறிஞ்சப்படுகின்றன வென்பதை ஆய்வுக்குட்படுத்தப்பட்ட சேர்வைகள் காட்டிவிட்டன. O. M. அளவு சார்புநிலையில் அதிகமாகக் காணப்படும் LHG மண்ணிலே இவ்வுறிஞ்சலாற்றல் மேற்பரப்பின் 1 அங்குலம் முதல் 2 அங்குலம் வரை செயற்படுகின்றது.

வெப்ப மென் பிளாசுமாவொன்றிலுள்ள தூசுத்துணிக்கைகளின் நிலைமின்னேற்றம்

தென்னகோன், கே. வஜ்ரநாயக்க, ஆர். எச்.

J. Natn. Sci. Coun. Sri Lanka 1977 **5** (2) :

வெப்ப மென் பிளாசுமாவொன்றிலுள்ள தூசுத் துணிக்கைகள் நேர் அல்லது எதிர்நிலை மின் ஏற்றங்களைப் பெற்றுக்கொள்ளக்கூடியனவென்பது விளக்கப்பட்டுள்ளது.

ஏலட்டு அயனிகளிலிருந்து கரைப்பான் ஒன்றுக்கு இடம்மாறிய இலத்திரன் ஒன்றின் கட்டுஞ்சக்தி

தென்னகோன், சே.

J. Natn. Sci. Coun. Sri Lanka 1977 **5** (2):

ஏலட்டு அயனிலிருந்து கரைப்பானொன்றுக்கு இடம்மாறிய இலத்திரனொன்றின் கட்டுஞ்சக்தியானது மின்நிலை அழுத்தத்திற்குட்பட்ட ஒரு முனைவு அல்லது இருமுனைவு சார் உறுப்புக்களை ஆய்ந்து கணக்கிடப்பட்டுள்ளது. ஏற்கெனவே சமர்ப்பிக்கப்பட்டுள்ள கோட்பாடுகளில் விதந்துரைக்கப்பட்ட வண்ணம் தரைநிலைச்சக்தியானது கட்டுக்கடங்காத உயர் மட்டத்தில் இருப்பதில்லை என்பதும் இங்கு விளக்கப்பட்டுள்ளது.

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