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STUDIES ON THE EFFECT OF PRE-STORAGE INSECTICIDAL TREATMENTS ON INSECT INFESTATIONS IN STORED PADDY

BY

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THESIS

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CERTIFICATE

This is to certify that the thesis herewith submitted contains the results of bonafide research work carried out by Sri Varghese, K.C., under my supervision. No part of the work embodied in this thesis has been submitted earlier for the award of any degree.

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INTRODUCTION

Careful storage of a commodity is next in importance to its production, as whatever energy and expenses spent on the latter runs to waste if it is not properly and economically stored and conserved. For a predominently agricultural country like India where diminishing returns from the land is more a matter of course rather than one of accident and where more and more food has to be found to feed the rapidly increasing population, the problem of storage of the agricultural commodities is a matter of prime importance.

Rice is more subject to deterioration and destruction than other cereals. Khan (1948) estimated the average annual loss by Sitophilus or*zae L alone in India to be 1 lakh tons of stored rice. Narayanan (1953) estimated the annual loss due to insect pests to be 5% of the total food grains stored or roughly 2.5 million tons. So it is a matter of utmost importance to protect our rice while under storage, especially at this time when India is passing through a state of national emergency and the existing production is hardly sufficient to feed the people.

Rice, the staple food of Kerala, is stored in the unhusked form for long periods either for consumption or for seed purposes. In storage this is subject to considerable damage by a variety of insects. Pruthi and Singh (1943) recorded that about 50 species of pests are found damaging rice in storage, among which the Angoumois grain moth, Sitotroga cerealella Oliv. and the lesser grain borer, Rhizopertha dominica Fab. are of major importance in Kerala. (A list of pests found in association with stored rice is appended).

Control measures like fumigation, though effective against insect infestation, is difficult to be applied in rural areas on account of meagre godown facilities. Stracener (1934) reported that rice is resistant to the penetration of heat and gases. Use of insecticides with persistent effect and low mammalian toxicity appears to be more advisable to protect stored rice from insect infestations.

Very little work has been done in India on the use of insecticides to control insect infestations in stored rice. Narasimhan and Krishnamoorthi (1944) reported that burnt paddy husk in finely powdered form mixed with rice causes a high percentage of mortality of insect pests. Israel and Vedamurti (1953) revealed that by mixing the grain with dried powder of the rhizome of Sweet flag (Acorus calamus) insect infestation is prevented by both killing and deterent effects.

Pretreatment of the grains with appropriate insecticides before being stored is a relatively new line of thought in store pest control in this country. Majumdar et al (1961) suggested a pre-harvest application with malathion for the safe storage of wheat. A pre-harvest application of insecticides has some inherent draw backs. Besides involving additional expenses, there is also the risk of the grains losing much of the insecticide deposits on them during the processes of threshing, drying and cleaning. Therefore application of the insecticide on the grains just before being stored was considered more advantageous and effective. The present investigations were therefore undertaken to find out the effect of pretreatment with insecticides before being stored, on insect infestation in rice under storage.

Necessarily, the insecticides used in such treatments should be non-hazardous. Hence malathion, pyrethrin and lindane which are relatively non-hazardous have been used in these investigations. Results are interesting and encouraging.

Literature on the prevention and control of insect infestation in stored rice have been reviewed.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Various methods have been recommended and practiced from early times to prevent and control insect infestation in stored rice. Following is a review of work done on the prevention and control of insect pests in stored rice.

FUMIGATION:

The earliest record of the use of fumigants to control pests in stored rice is that of Lyne (1912). He found that the use of carbon disulphide at the rate of 1 lb. for every tone of rice with an exposure of 36 hours was sufficient to kill all insects confined in the grain. Duport (1915) observed that fumigation with carbon disulphide was effective to control rice weevil infestation in stored rice. Ehrhorn (1918) also recorded the effectiveness of CS_2 fumigation in rice.

Shinsuke (1918) found that fumigation of rice grain with carbon disulphide at the rate of 5¼ ozs. for 35 cuft. of grain before storage was effective to preserve the grain from insect infestation. The rice grains had to be exposed to the gas for a period of 24 to 48 hours. Treherne (1918) recorded that an all-night sulphur fumigation did not give sufficient control of Sitophilus orizae L. in rice, when 20 lbs. sulphur was burnt in an iron carrier which was 43 ft. long, 18 ft. wide and 8 ft. deep.

Jack (1923) observed that fumigation of rice in airtight bins with 2 to 3 lb. liquid carbon disulphide 10 1000 cuft. space was effective to control all insect pests. Lord (1928) also recommended the carbon disulphide fumigation to control insects in rice stored in bags.

Back <u>et al</u> (1930) observed that ethylene oxide as a fumigant at the rate of 1 lb. per 1000 cuft. of rice in bulk was effective in controlling insect pests in it. Squire (1933) found that fumigation of rice was difficult owing to its impenetrability. He recommended naphthalene to control insect attack. Stacener (1934) in Louisiana found that spread of the pests within the store house was more rapid than in the fields. He suggested fumigation of stored rice with CS_2 in the store house, when the quantity is very low. He noticed that CS_2 was non-inflammable and effective to control infestation when used at the rate of 5½ lbs. per 1000 cuft. space.

Commun (1934) found that carbon tetra chloride was effective to protect stored rice in large granaries when jars containing 13 ozs. CCl_4 placed at intervals of about 2 yds. and 18" deep in the layer of rice grains (which should be 2 ft. thick) and left for 48 hours. Hargreaves (1936) in his fumigation trials with CS_2 against pests of stored rice observed that an exposure of 48 hours at a concentration of 7½ lbs. per 1000 cuft. was effective.

Kono (1937) in Japan carried out experiments with chloropicrin for the control of Sitophilus orizae L. and the results showed that at 30°C it killed all larvae and pupae in 3 hours and the adults and eggs in one hour when applied at the rate of 1 lb. per 1000 cuft. of air. Strong (1937) reported that chloropicrin fumigation of rice gave complete mortality of adults of rice weevil in storage bins. According to him the amount of gas required depended upon the quantity of rice fumigated than the space in storage.

Hargreaves (1937) found that there was no decrease in germination of rice when it was fumigated with carbon disulphide at the rate of 6 lbs per 1000 cuft. or stored in containers with para dichlorobenzene at the rate of 0.357 to 1.79 gm. per 1000 cc. Fukuda (1937) studied the efficacy of chloropicrin as a fumigant against Sitophilus oryzae L. in rice and found that its efficacy increased with the temperature up to 30°C but decreased at 35°C.

Strong (1938) reported that the fumigation of rough stored rice with HCN gas at the rate of 3/4 lb. liquid HCN per 1000 cuft. of space for 72 hours at 80°F killed all insects in it. Atmospheric fumigation of cleaned rice with HCN was not effective because the outer parts of the mass was observed to absorb much of the gas. Mathlein (1938) tried HCN as a fumigant against rice weevil, Sitophilus oryzae using a gas concentration of 1.2 to 1.3 volume per-cent for 10 days at a temperature of 30°C. No live insects could be detected in the grain after two weeks and after several months of storage the rice was still uninfested. Nakayama (1939) in his experiments with chloropicrin fumigation against Plodia interpunctella Hb. in stored rice in South Korea found that fumigation at the rate of ½ lb. per 1000 cuft. for 30 to 40 hours at 24 to 28°C killed 84 to 100% of the insect population.

The investigation by Geijskes (1940) showed that Sitophilus oryzae, Rhizopertha dominica and S.cerealella in unhulled rice could be effectively controlled by better condition of storage and fumigation with carbon bisulphide. Strong (1940)claimed that complete control of insects was achieved when 3½ million pounds of rice stored in burlap bags in gas tight concrete ware-houses was fumigated with methyl bromide at the rate of 0.85 oz. per 1000 lbs. of rice for a period of 42 hours. Fans were used to distribute the gas. He also found that fumigation at the rate of 1½ ozs. per 1000 lbs. of rice at 70°F gave complete mortality in brewers rice stored in clean sacks after an exposure of 4 hours and a dosage of ½ oz. was effective with an exposure of 12 hours.

Corbett and Pagden (1941) in a review of some investigations concluded that local storage condition rendered fumigation practically impossible, but chloropicrin was effective in small air-tight stores of sacked rice. High dosages of carbon dioxide did not give complete mortality of rice pests, but low concentration inhibited insect activity and might be useful for the protection of rice in the husk. Investigations in Malaya (1941) showed that the penetration of chloropicrin into tightly packed stored rice when used alone or mixed with an equal quantity of CCl_4 at ten times the dosage normally employed did not exceed 5 ft. in four days. An exposure for more than two weeks was necessary to destroy all stages of the weevil in infested rice. Cotton and Wagner (1941) found that chloropicrin or mixture of Ethylene dichloride and CCl_4 could be utilised for fumigation of rice in country elevators.

Balzer (1942) observed that satisfactory kill of insects in rough rice stored in covered wooden cribbed bins could be obtained by introducing crude granular calcium cyanide into the grain stream as the bin was being filled. The dosage used was 8 lbs. per 360 bushels. Further, he tried fumigation of rice mills with HCN and methyl bromide for all types of fumigation, a mixture of ethylene oxide and carbon dioxide (1:9) for vacuum chambers and chloropicrin for atmospheric chambers. The result showed that methyl bromide was effective for rice in different types of packages in atmospheric or vacoum chambers while rough or milled rice stored in bags in suitable buildings could be fumigated with HCN gas applied through a piping system at the rate of 1:1000 cuft. space.

Schwardt and Wylee (1943) observed that methyl bromide fumigation at the rate of 8 ozs. per 1000 cuft. killed insects in stored rice within 2 ft. of the bottom, but was not effective against those in higher levels owing to the heaviness of gas. Glass (1944) stated that the dosage of ethylene oxide and CO_2 (1:9) could be reduced by 25% if the gas was recirculated in the vacuum chamber by means of a vacuum pump and by-pass. Lever (1945) suggested the fumigation of rice with carbon bisulphide to control insects like <u>Sitophilus oryzae</u>, <u>Tribolium castaneum</u> and others.

Clegg and Lewis (1953) found that no loss of vitamin B occured when fumigated with methyl bromide. Muthu and Pingale (1955) found that ethylene dibromide at the rate of 20 cc. per bag gave more effective control of the pests than by CCl_4 or methyl bromide or a mixture of EDCT (3:1) when injected into the centre of the bag. Samples taken from rice after 7 days showed that in the treatment with 20 cc. ethylene dibromide per bag there was a residual deposit of 12 to 31 ppm. which was not considered as harmful. Israel and Vedamurti (1956) observed that rice weevil and rice moth started infesting rice in the field and reached the store along with the harvested grain. They recommended fumigation with chlorosol at the rate of 4 lbs. per 100 maunds before stocking the same.

Cogburn and Tiltan (1963) made studies on the effectiveness of phosphine as a fumigant for sacked rice under gas tight tarpaulins. A dosage between 73 and 121 tablets per 1000 cuft. (3 gms. tablet of Aluminium phosphide and NH_4CO_3) was found sufficient for complete kill of immature stages of S.oryzae L. in rough rice when the temperature varied from 52 to 58°F. Further, no deleterious effect on germination could be noticed by any dosage of this fumigant.

Use of stomach and contact poisons:

Various inorganic and organic insecticides and those of vegetable origin had been in use for the control of insect pests in stored rice. Isaac (1931) reported that mercury could be utilised effectively to control insect pests by keeping it within the stores. Square (1933) found that the use of Melia azedarach or Pepper capsicum as a repellent proved valueless. However, he observed that sodium fluosilicate stirred with the rice within bags at ½ lb. per bag gave promising results causing 83% mortality in rice weevil.

Okada (1936) found that Boric acid at the rate of 1:800 by weight when put with the grain in tightly closed vessels was effective to control rice weevils. Kuo (Li-sein) (1937) also obtained similar results in controlling S.oryzae in rice with boric acid at the rate of 1:750 by weight in tightly closed containers or upto 1:500 under less air tight conditions. Stracener (1937) showed that 6 ozs. derris mixed with 100 lbs. rice before sacking killed all insects and that it had a considerable repelling effect. It could not be used with milled rice as the stain from the derris could not be washed out. When derris was dusted outside the bags of rice infestation was found to be less than 1% after 8 months. He recommended a programme of control consisting of eliminating all insects from ware-houses by cleaning, fumigation and spraying walls and floors with contact insecticides (equal parts of kerosine and fuel oil).

Richardson (1943) studying the toxicity of derris, nicotine and pyrethrum to the eggs of S.cerealella infesting rice found that pyrethrin I and II at a concentration of 0.007% were much more toxic than nicotine sulphate 0.07%. Dole (1943) observed that mercury applied on sheets of copper were highly toxic to the larvae of S.oryzae and R.dominica. Narasimhan and Krishnamoorthy (1944) found that burnt paddy husk in finely powdered form (100 mesh to an inch) thoroughly mixed with rice at the rate of 1% by weight of the grain adhered to them exceedingly well and caused 100% mortality to R.dominica under laboratory conditions. When mixed with sound grain the powder repelled the insects to a marked degree.

Krishnamoorthy and Seshagiri Rao (1945) confirmed the effectiveness of finely gound rice-husk-ash to destory stored insects. They also found that spraying with petrol or kerosene extract of pyrethrum in storage premises gave high mortality of adults of Corcyra cephalonica and S.cerealella but was less effective against those of Tribolium, R.dominica and S.oryzae. Tests conducted in British Guiana (1945) revealed that DDT at the rate of 1 part to 50,000 parts of rice destroyed all weevils in 72 hours. Farrar and Wright (1946) observed that dusts containing 2.5%, 5%, 10% and 20% DDT with pyrax when added to the rice at the rate of 1 oz. per bushel stored in open bags gave excellent protection for 1 year from insect infestation. Gosh (1947) found that a 5% BHC dust applied to rice in bags at the rate of 1½ lb. per 165 sq.ft. of exposed area controlled the pest and the infestation was not apparent for six months following dusting.

Israel and Vedamoorthi (1953) at Cuttack studied the effectiveness of powdered rhizome of Acorus calamus, popularly known as "sweet flag" and found that either the grain or milled rice when mixed with the powder at the rate of 1 lb. in 100 lbs. posessed both killing and deterrent effects more than those obtained with BHC or DDT dusts. The grain thus treated did not cause any unpleasant odour in the cooked rice. Floyd and Smith (1953) carried out investigations on the effectiveness of lindane and pyrethrin in protecting rough rice from pest incidence, especially from those of Sitotroga cerealella and R.dominica. The pyrethrum products were applied as fine mist sprays or as dusts sprinkled by hand and lindane (5% dust) mixed with the rice. Examinations were made 7, 10 and 11 months after treatment. Pyrenone grain protectant (a dust containing 0.05% pyrethrin and 0.8% piperonyl butoxide) was used in all tests of the pyrethrum products and their application theoretically afforded the equivalent of 0.032 ozs. piperonyl butoxide and 0.002 ozs. pyrethrins per hundred-weight which were referred to as "standard dose".

Dusts appeared to be superior to emulsion or wettable spray of pyrethrums, possibly because the husk absorbed much of the liquid and so prevented a lethal concentration of the deposit on the surface. But all gave good protection for 7 months when applied at the standard dose. Pyrethrins at twice the standard dose was the most effective giving good protection for 10 to 11 months and lindane at 3 gm. per Cwt. gave practically complete protection throughout the period. Lindane caused no tainting of rice.

Li (Ching-sing) (1953) made studies on the control of S.oryzae and T.castaneum in stored rice by means of impregnated dusts containing 5% DDT, 5% BHC or 1.5% Rotenone. He mixed these dusts with unhusked paddy at the rate of 25, 50, 100 or 250 mg. per 400 gm. of paddy and then exposed to infestation by 100 adults of Tribolium and 30 adults of S.oryzae for 5 weeks. The results showed that BHC was more rapid in action than DDT or Rotenone and that gamma BHC and DDT gave much higher kill than Rotenone. Tribolium was found to be more susceptible to the insecticides than S.oryzae. BHC gave complete kill of both in one week at 100 mg. and very high mortality in two weeks at 50 mg.

Prevett (1959) found that S.cerealella and S.oryzae infested rice in the field either before harvest or during drying prior to threashing, but only S.cerealella could continue thereafter to breed in good quality paddy.

In an experiment conducted to compare the effectiveness of lindane and malathion for the protection of stored paddy (par-boiled) in bags against Rhizopertha dominica he found that admixture of lindane with paddy at the rate of 5 ppm. was more effective than malathion dust applied to the outside of the bags. Admixture of gamma BHC (lindane) combined with external application was the most effective among treatments. He also indicated that malathion was more persistent than lindane. On the basis of these results he recommended that the rice for long term storage should be in the form of raw paddy. Raw or par-boiled paddy should be stored in bulk and lindane should be mixed with surface layer especially in case of par-boiled rice. The same dust should be mixed with paddy stored in bags and the bags dusted with 1% malathion at monthly intervals. Majumdar et al (1960) remarked that impregnation of jute bags with lindane (75 mg. per sq. ft.) would help to maintain the stock insect free to start with. He found that the effectiveness of this treatment was dependent upon the texture of the jute bag.

Bang and Floyd (1962) carried out experiments in Louisiana with malathion in 10 lb. sample of polished rice. Malathion was used as dust and spray at dosage levels of 4 ppm., 8 ppm., 16 ppm. and 25 ppm. The results showed that by either method of application malathion at 8 ppm. gave complete protection against Sitophilus oryzae for 5 months. Dosages of 4 ppm. did not give sufficient protection against this weevils after 3 months. At 16 and 25 ppm. levels in the dust form and 25 ppm. level as sprays, the treatments gave complete protection against Tribolium castaneum for 1 month but gradually decreased in effect after 3 to 5 months. Lower rates of application were found relatively ineffective. Exposure of adults of S.oryzae for 10 days to rice treated five months previously with 8 ppm. of malathion gave complete mortality and similar exposure to rice treated with 4 ppm. in sprays and dusts caused 89% and 99% mortality respectively. On residue analysis of malathion it was found that residue in rice sprayed and dusted with malathion at 8 ppm. were respectively 7.1 and 7.3 ppm. immediately after treatment, 5.8 and 5.2 ppm. after a month and 1 and 0.7 ppm. after 3 months.

Bowling (1964) studied the effect of aldrin on seed rice germination and found that the germination was not significantly affected with aldrin at rates of 4 oz. and 8 oz. toxicant per 100 lb. seeds.

Other methods of control:

Shinsuke (1918) stated that the best preventives from the attack of Sitotroga cerealella and Sitophilus oryzae were cleanliness of the store house and isolation of the infested rice. He suggested that the store house should be thoroughly disinfected with 5 to 10% formalin before use. Lyne (1919) reported that all insects infesting rice were killed after an exposure of 14 days below freezing. Exposure to 130°F for 3 hours gave the same results, but heat appeared to spoil the rice for milling.

Dendy and Elington (1920) observed that rice grains which are clean and dry are least attractive to insects. He found that insects could not thrive in rice with a moisture content of 8% or less. Robinson (1926) found that if the temperature of the rice grains could be brought below 35°C most of the insects would die. De Ong (1934) found that a combination of specially prepared calcium carbonate and imported talc which had long been used in California for coating the rice in order to retain its flavour, protected rice from injury by different insects. Schwardt (1934) observed that infestation of rice could be reduced by the removing and burning the loose accumulation of the bye-products from the stores, periodically. Square (1935) observed that 1 lb. calcium carbonate per 180 lb. rice was effective in preventing weevil infestation for at least eight months.

Corbett (1937) showed that sunning of rice for eight hours failed to destroy immature stages of R.dominica and S.cerealella. Maximum temperature obtained was 115°F. Frappa (1938) found that the adults of R.dominica in rice were killed by exposure for 3 minutes to a temperature of 50°C. Kawano (1939) concluded from his investigations that rice stored at a temperature of 15°C or lower could ward off infestation.

Nakayama (1939) observed that <u>Plodia interpunctella</u> in stored rice could be effectively controlled by exposure of the grain to 120°F to 130°F for five to six hours. Cotton <u>et al</u> (1940) studied the relation of moisture content of the rice grain to its susceptibility to insect attack and found that the grain which was clean and dry was least attractive to insects.

Douglas (1941) suggested that the insect damage could be reduced by cleaning the storage structures and disposing of all old accumulations of rice grains. Cotton <u>et al</u> (1941) recommended thorough cleaning of the go-down and fumigation with calcium cyanide at the rate of 3 lb. per 1000 Cuft. of air for 24 to 34 hours to destroy any insects that might be present in the storage structure. Cotton and Wagner (1941) found that the exposure of the rice grains to a temperature of 140°F for 10 minutes killed all insects in it.

Corbett (1941) noted that exposure of stored rice to a temperature of 60°C for 45 minutes killed all insects. Balzer (1942) found that all insects in the empty warehouses could be killed by spraying 5% pyrethrum in Kerosene. Balzer in another experiment on stored rice found that drying thoroughly of moist rice and rice products reduce their susceptibility to insect damage. He recommended the exposure of grains to a temperature of 140°F for 10 minutes to destroy the pests. But he was of opinion that heating was an unsatisfactory practice as the quality of the rice grain might be affected.

Krishnamurthi (1943) recommended spraying of petrol or Kerosene extract of pyrethrum in empty godowns. Cheo and Chang (1943) recorded that covering stored rice with a layer of sand 2 to 4 cm. thick and storing in unhusked condition prevented weevils from entering into it and those which had already made their way into the sand eventually died of starvation. Annand (1945) found that white lead paint, whitewash and a solution of nicotine sulphate were all effective in preventing Tenebroides mauritanicus and Rhizopertha dominica from entering the wood work bins and infesting the rice subsequently stored in it.

Dresner (1949) observed that all adults of Sitophilus oryzae kept in rice grains at 65 to 85°F and 35 to 85% relative humidity were killed in 13 days, when dusted with 0.3% by weight of pure spore material of the fungus

Beauvaria bassiana. Working on Rhizopertha dominica, Sitotroga cereallella and Sitophilus oryzae Chatterjee (1953) found that at a moisture content below 12%, rice grains were less damaged by the above three pests. Salmond (1956) made an entomological survey of rice markets and stores in the northern and central provinces of Nyasaland which revealed that before being husked stored rice was attacked chiefly by Rhizopertha dominica, S.oryzae and S.cerealella. Termites also attacked bagged rice. He observed that infestations could be prevented by a layer of 2 to 3 inches fine sand or 1 inch wood ash under dunnage. Prevett (1958) observed that raw paddy with a moisture content of 13 to 15% could be safely stored in bags for a year without infestation.

Mukherji (1961) working on Sitophilus oryzae in rice found that under air-tight conditions the pest was unable to breed irrespective of the moisture conditions of the grain. Majumdar et al (1962) found that Tribolium castaneum in milled rice could be successfully controlled by mixing the grain with the spore powder of Bacillus thuringiensis at the rate of 1 part per million.

MATERIAL AND METHODS

MATERIAL AND METHODS

A. MATERIAL:

Paddy grain used: The variety used for the experiment was "PTB 10", a short duration variety obtained from the Farm of the Agricultural College and Research Institute, Vellayani.

Jute bags: Sixty six bags made of jute each measuring 28cms. x 20 cms. were used for the experiment.

Test Insecticides: The following insecticides were used:-

Malathion: (2 di (ethoxy carbonyl) ethyl di methyl phosphorothiolothionate). A technical grade containing 95% active ingredient, obtained from Cyanamid India Ltd., was used for the experiment.

Lindane: Lindane used in the test was a technical product containing 99.5% gamma Benzene hexa chloride obtained from Tata-Fison (Private) Ltd., Bombay.

Pyrethrins: 'Pyrocone E', a proprietory emulsifiable formulation containing 1 part pyrethrins and 10 parts piperonyl butoxide, manufactured by Bombay Chemical (P) Ltd., was used for the experiment.

Teepol: This detergent, a product of Shell Chemicals was used as an emulsifier to prepare the emulsions with malathion and lindane.

Spraying apparatus: An atomiser worked with a compression pump was used for spraying the grains and the bags with the insecticides in the laboratory.

Glass wares: These consisted of specimen tubes (7.5 cms. x 2.5 cms.), Conical flasks, pippettes of 1 cc. and 2 cc. capacities, measuring cylinders of 100 cc. and 1000 cc., beakers of 100 cc. and 250 cc. and glass rods.

Tube stand: A stand measuring 135 cms. x 38 cms. to hold 72 tubes was used for the experiments in the laboratory.

Grain Extractor: A grain extractor of the conventional type, measuring 18 cms. in length with the inner side concave, to hold a small quantity of the grains and having a pointed tip for piercing the gunny bags and a wooden handle, was used for extracting the grains from the bags stored in the godown.

B. METHODS:

Conditioning of the grains: The paddy grains required for the experiment were thoroughly cleaned to remove all foreign materials and put in water to remove chaff and other under-developed grains. The good grains were collected and dried in the sun for 2 hours.

Preparation of the spray solutions: For each insecticide three different concentrations were tried. In the case of the technical materials (malathion and lindane) a stock solution in benzene was prepared from which the lower concentration of emulsions were obtained by mixing with water containing, 1% emulsifier. The emulsifier used was Teepol. The propertions of the solutions, emulsifier and water were so adjusted that the percentage of benzene in all the dilutions was kept constant at 5% level.

Following are the details of the preparation of the dilutions of the different insecticides.

<u>For treating the grains</u>:

<u>Lindane</u>:

Stock solution 1 (S_1):- 0.5 gm. lindane + 10 cc. benzene = 5% solution

Stock solution 2 (S_2):- 2 cc. S_1 + 18 cc. benzene =.5% solution.

Dilutions of emulsions:- 1) 3 cc. S_2 + 12 cc. benzene + 135 cc. 1% Teepol solution. (40 cc. emulsion contain 4 mg. lindane)

2) 6 cc. S_2 + 9 cc. benzene + 135 cc. 1% Teepol solution. (40 cc. emulsion contain 8 mg. lindane)

3) 9 cc. S_2 + 6 cc. benzene + 135 cc. 1% Teepol solution. (40 cc. emulsion contain 12 mg. lindane).

<u>Malathion</u>:

Stock solution 1 (S_1):- 0.5 gm. malathion + 9 cc. benzene = 5% solution.

Stock solution 2 (S_2):- 4 cc. S_1 + 16 cc. benzene = 1% solution.

<u>Dilutions of emulsions</u>:-

1) 3 cc. S_2 + 12 cc. benzene + 135 cc. 1% Teepol solution. (40 cc. emulsion contain 8 mg. malathion)

2) 6 cc. S_2 + 9 cc. benzene + 135 cc. 1% Teepol solution. (40 cc. emulsion contain 16 mg. malathion)

3) 9 cc. S_2 + 6 cc. benzene + 135 cc. 1% Teepol solution. (40 cc. emulsion contain 24 mg. malathion).

<u>Pyrethrin</u>:

The lower concentrations used in the experiment were prepared by mixing pyrocone E with water as follows:-

1) 1 cc. pyrocone E + 399 cc. water. (40 cc. emulsion contain 1 mg. pyrethrin and 10 mg. piperonyl butoxide).

2) 2 cc. pyrocone E + 398 cc. water (40 cc. emulsion contain 2 mg. pyrethrin and 20 mg. piperonyl butoxide).

3) 4 cc. pyrocone E + 396 cc. water (40 cc. emulsion contain 4 mg. pyrethrin and 40 mg. of piperonyl butoxide).

<u>Solution for treating the bag</u>:

For bag treatment each insecticide was used at a single dose the details of which are given below:-

<u>Malathion</u>:

This was used at 7.8 mg. per bag of 1120 sq.cm. bag surface. For this the emulsion was prepared as follows:-

S= 0.5 gm. malathion + 9 cc. benzene = 5% solution.

2 cc. S + 4.4 cc. benzene + 57.6 cc. 1% Teepol solution

= 0.156% emulsion.

The specified deposit was obtained by spraying 12 bags with 60 cc. of the emulsion.

<u>Lindane</u>:

This also was used in the concentration as that of malathion.

S = 0.5 gm. lindane + 10 cc. benzene = 5% solution.

2 cc. S + 4.4 cc. benzene + 57.6 cc. 1% Teepol solution

= 0.156% emulsion.

The rate of application was the same as in the case of malathion mentioned above.

<u>Pyrethrin</u>:

This was applied on the bag so as to give a deposit of 0.28 mg. pyrethrin per bag of 1120 sq. cms. of bag surface.

The solution was prepared as follows:-

1 cc. Pyrocone + 178 cc. water. When 60 cc. of this emulsion was applied on 12 bags the required deposit was obtained.

Treatment of the jute bags: All the jute bags intended for treatment with the insecticides, which numbered 12 for each insecticide, were arranged close to one another, but not overlapping, on a paper spread on floor. Thirty cc. of the concerned insecticide was sprayed evenly on the upper surface of the bags with the help of the atomiser as shown in Fig.5. After about 15 minutes by which time the sprays had been absorbed and dried, the bags were turned upside down and the other side also sprayed in the same way. Then the treated bags were dried in shade for about 1 hour.

Treatment of the grains: The conditioned grains were weighed out into 1 kg. lots. For the treatment of the grains with the insecticides, each lot was spread in a thin layer on a paper laid on the floor. The concerned insecticide was then sprayed on this layer of grains (see figure 6). When the exposed surface of the grains was fully covered with the spray the grains were mixed up, spread again in a thin layer and sprayed again. This repeated till all the required amount (40 cc.) of the spray fluid was sprayed on the 1 kg. samples of the grains. Then the treated grains were dried in shade and stored in the respective gunny bags. The top of the bags were stitched properly and the bags labelled.

Exposing the treated grain to insect infestation: With a view to assess the efficacy of the different insecticide pre-treatments to protect stored paddy from insect infestation under godown conditions, the lots of grains under the various treatments were arranged at random in a circular manner inside the godown. A stock culture of "PTB.10" paddy grains heavily infested with S.cerealella, R.dominica, S.oryzae and other insects was placed inside the circle as shown in Figure 7. Treated lots (replicated thrice) along with the "control" lots were arranged randomly for natural infestation.

Assessment of the results: To assess the results, samples were examined from each lot at monthly intervals. For this, the grains were drawn from the bags with the grain extractor from different regions of each bag for obtaining a complete representation of the grains in each treatment. Approximately 20 gm. of grains were drawn from each bag and kept in specimen tubes in the laboratory for 15 days for the emergence of any insect already present inside the grains (See Fig.8).

After 15 days, these grain samples were spread on a paper, 500 grains randomly selected and examined individually. Those showing insect injury were counted as damaged. Percentage of grains attacked was used as the index of the degree of infestation.

Experimental conditions: The experiments were conducted during the period from October 1964 to May 1965. The data on temperature and humidity for the period are given in Appendix III.

Design of the Experiment and Statistical studies: The completely randomized design was adopted in the experiment in the present investigation. The data were statistically analysed using the analysis of variance technique.

EXPERIMENTAL DETAILS AND RESULTS

EXPERIMENTAL DETAILS AND RESULTS

Effect of pre-storage treatment with malathion, lindane and pyrethrins on insect infestations in stored paddy

Experimental Details:

Paddy grains used	-	"PTB 10"
Insecticides	-	Malathion, lindane and pyrethins. These were used as emulsions.
Treatments	-	There were 22 treatments including one control details of which are given below:
T1	-	Grains treated with malathion at 8 ppm. and bag sprayed with malathion at 7.8 mg. per bag surface.
T2	-	Grains treated with malathion at 8 ppm. and bag not treated.
T3	-	Grains treated with malathion at 16 ppm. and bag sprayed with malathion at 7.8 mg. per bag surface.
T4	-	Grains treated with malathion at 16 ppm. and bag not treated.
T5	-	Grains treated with malathion at 24 ppm. and bag sprayed with malathion at 7.8 mg. per bag surface.

T6 - Grains treated with malathion at 24 ppm. and bag not treated.

T7 - Grains not treated and bag treated with malathion at 7.8 mg. per bag surface.

T8 - Grains treated with lindane at 4 ppm. and bag sprayed with lindane at 7.8 mg. per bag surface.

T9 - Grains treated with lindane at 4 ppm. and bag not treated.

T10 - Grains treated with lindand at 8 ppm. and bag sprayed with lindane at 7.8 mg. per bag surface.

T11 - Grains treated with lindane at 8 ppm. and bag not treated.

T12 - Grains treated with lindane at 12 ppm. and the bag treated with lindane at 7.8 mg. per bag surface.

T13 - Grains treated with lindane at 12 ppm. and bag not treated.

T14 - Grains not treated and bag treated with lindane at 7.8 mg. per bag surface.

T15 - Grains treated with pyrethrins at 1 ppm. and bag treated with pyrethrins at 0.28 mg. per bag surface.

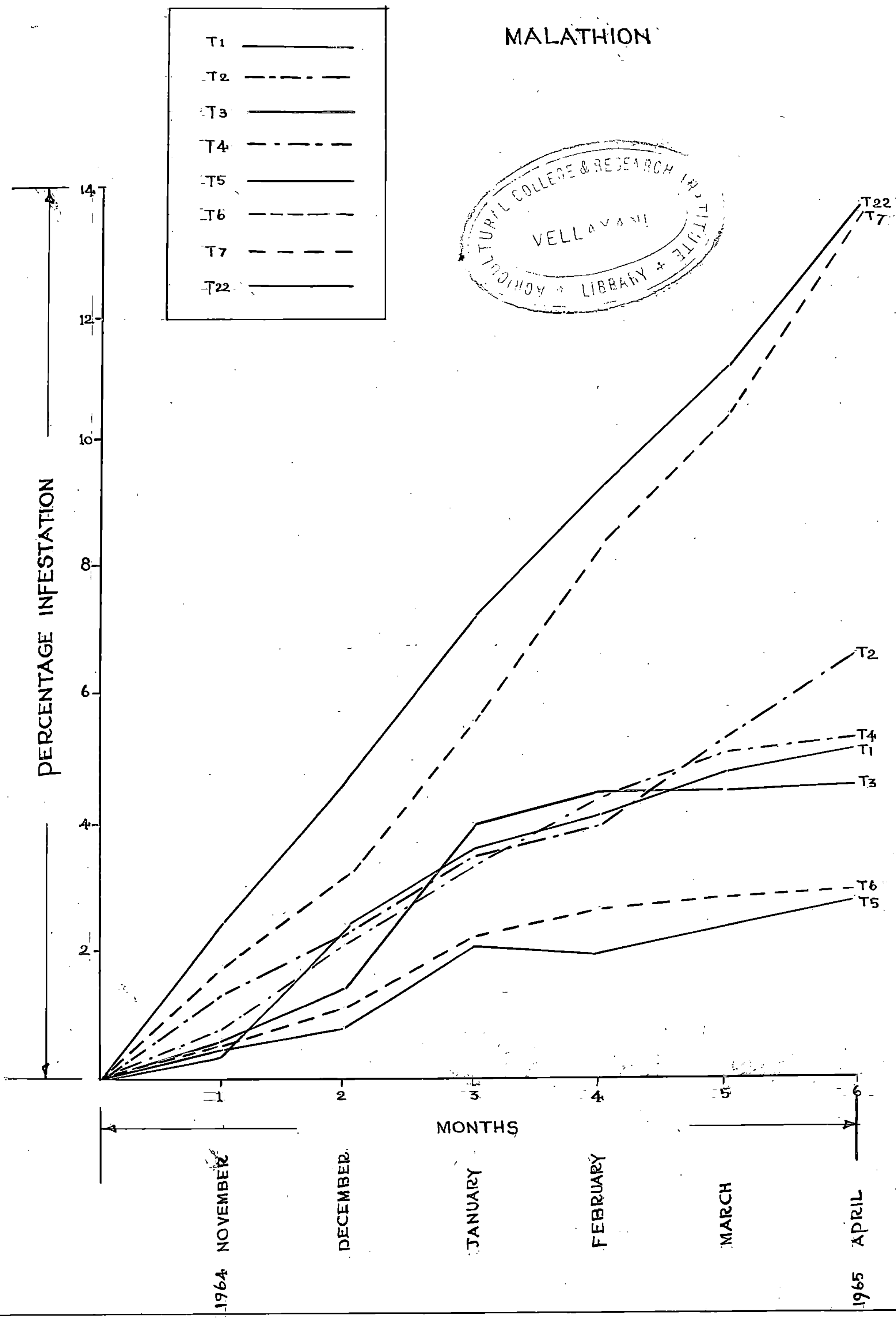
T16 - Grains treated with pyrethrins at 1 ppm. and bag not treated.

T17	-	Grains treated with pyrethrins at 2 ppm. and bag treated with pyrethrins at 0.28 mg. per bag surface.
T18	-	Grains treated with pyrethrins at 2 ppm. per bag surface.
T19	-	Grains treated with pyrethrins at 4 ppm. and bag treated with pyrethrins at 0.28 mg. per bag surface.
T20	-	Grains treated with pyrethrins at 4 ppm. and bag not treated.
T21	-	Grains not treated and bag treated with 0.28 mg. pyrethrins per bag surface.
T22	-	Grains and bag not treated (Control).

Number of replication	3 for each treatment.
Quantity of paddy used for each treatment -	1 Kilogram.
Design of the treatment	Completely Randomised
Date of spraying of bag	26-10-1964
Date of spraying of grain	27-10-1964
Date of exposure of of the samples to natural infestation in the Godown	28-10-1964

Fig.1. Graph showing the effect of different doses of malathion treatments on insect infestation in paddy at monthly intervals.

FIG.1


MALATHION
T1
T2
T3
T4
T5
T6
T7
T22
PERCENTAGE INFESTATION
14
12
10
8
6
4
2
1
2
3
4
5
6
MONTHS
1964 NOVEMBER
DECEMBER
JANUARY
FEBRUARY
MARCH
1965 APRIL

Number of observations taken	- 6 (at monthly intervals)
Date at which observations were taken	- 1st on 28-11-1964
	2nd on 28-12-1964
	3rd on 28-1-1965
	4th on 28-2-1965
	5th on 28-3-1965
	6th on 28-4-1965
Temperature during the experiment.	given in Appendix III
Humidity during the experiment	given in Appendix III

<u>Procedure:</u> Samples of grains of the required replications were treated with the different insecticides as described on page 28. The bags were given the individual treatment by spraying the insecticides on them as detailed on page 26. The treated grains were exposed to pest infestation in the godown. Samples of grains were drawn from the test bags at monthly intervals and examined for insect infestation as described on page 27. The results were analysed statistically.

<u>RESULTS:</u> Results are given in Appendix I, Tables 1 and 2 and Figures 1, 2, 3 and 4. Appendix 1 gives the actual counts of damaged grains out of 500 grains examined. Table I shows

the percentage of grains damaged by insects observed at monthly intervals after treatment and storage. Table II gives the mean number of grains damaged out of 500 grains examined. The same results are represented in Figures 1, 2 and 3. It will be observed that none of the treatments give absolute protection of the stored paddy from infestation by the insects. It is also observed that the intensity of damage increases as time elapses. However it is evident that in general this increase in infestation is more pronounced in the case of untreated grain stored in bags treated with the insecticides and in the case of control ie. untreated grain stored in untreated bags, than in the case of grains treated with the insecticides. In the latter case a suppression in the cumulative infestation of grains by insects is evidenced. Comparison of the figures 1, 2 and 3 will show that treatment with malathion is the most effective in suppressing insect infestation in the grain and lindane the least effective; pyrethrins show intermediate effect.

Relative efficiency of all the treatments in preventing insect damage to stored grains is shown in Fig.4. The extended of damage caused to the grains under the various treatments, 6 months after treatments and storage is shown in this figure. It will be observed that on the whole malathion treatments are more effective followed in the descending order by pyrethrins and lindane. Malathion at 24 ppm.

Fig.2. Graph showing the effect of lindane treatments on insect infestation in paddy at monthly intervals.

FIG.2

LINDANE

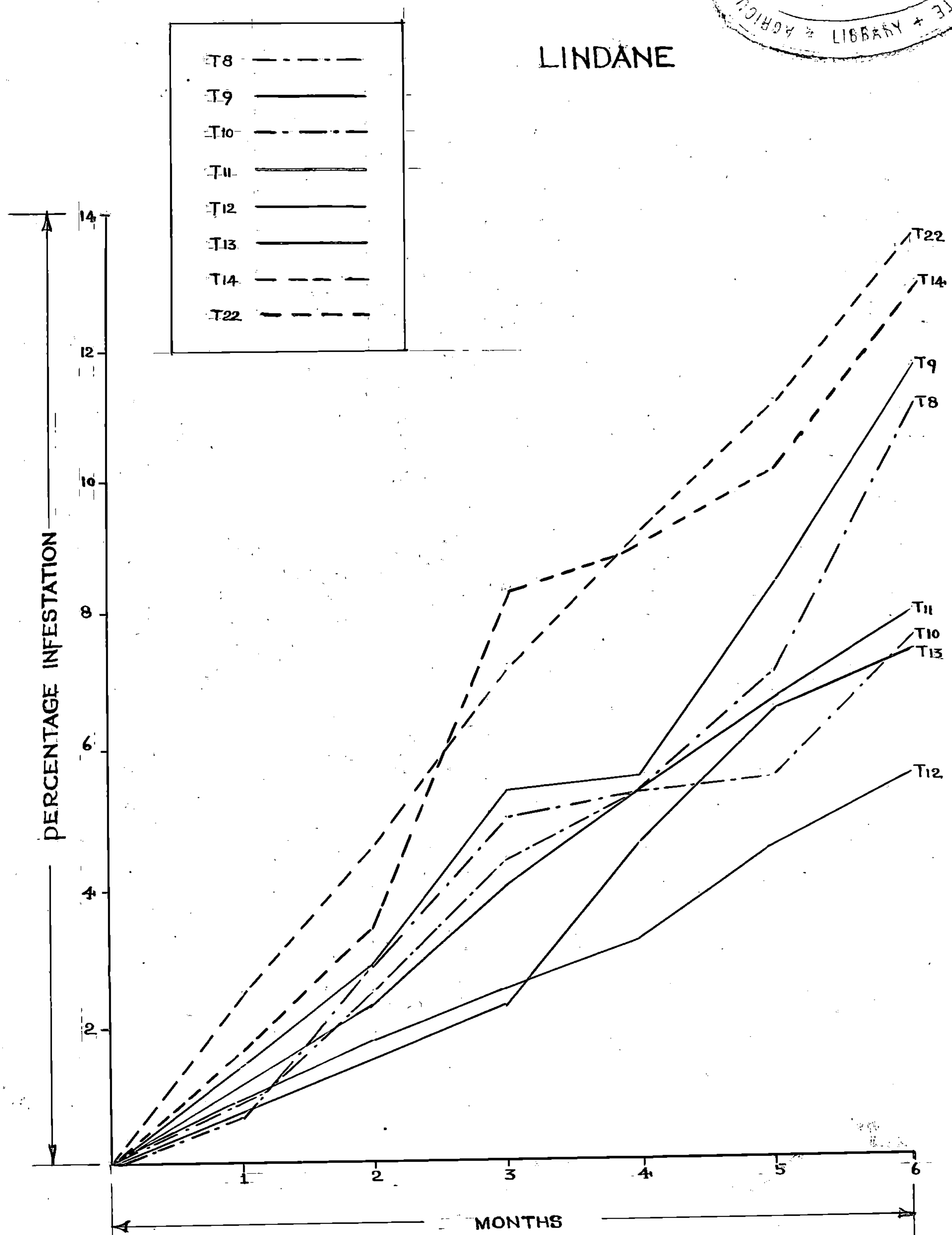


TABLE I

PERCENTAGE INFESTATION IN STORED PADDY UNDER PRE-TREATMENTS WITH MALATHION, LINDANE AND PYRETHRINS OBSERVED AT DIFFERENT PERIODS AFTER STORAGE

Treatments		Percent infestations					
		After months					
		1	2	3	4	5	6
Malathion	T1	0.4	2.4	3.6	4.1	4.8	5.1
	T2	1.4	2.3	3.5	4.0	5.3	6.6
	T3	0.6	1.4	4.0	4.5	4.5	4.6
	T4	0.8	2.1	3.3	4.4	6.1	5.3
	T5	0.5	0.8	2.0	2.0	2.4	2.8
	T6	0.66	1.06	2.20	2.6	2.8	2.9
	T7	1.8	3.5	5.6	8.4	10.2	13.6
Lindane	T8	0.66	2.8	4.9	5.4	7.1	11.2
	T9	1.43	2.8	5.4	5.6	8.5	11.8
	T10	0.8	2.5	4.4	5.4	5.6	7.7
	T11	1.2	2.3	4.1	5.4	6.8	8.0
	T12	0.8	1.8	2.5	3.2	4.6	5.6
	T13	0.8	1.6	2.3	4.7	6.6	7.2
	T14	1.6	3.4	8.3	9.1	10.2	13.0
Pyrethrins	T15	0.6	2.5	5.0	5.0	6.6	7.3
	T16	0.8	2.7	4.0	5.2	5.8	6.3
	T17	0.6	1.6	3.0	3.2	5.7	6.4
	T18	0.73	1.8	4.0	4.4	4.4	4.8
	T19	0.4	1.6	1.8	2.1	3.3	4.4
	T20	0.6	1.7	2.4	4.1	4.8	5.1
	T21	1.4	3.0	7.1	9.0	11.0	13.2
Control	T22	2.5	4.6	7.2	9.3	11.2	13.7

Fig. 3. Graph showing the effect of pyrethrins treatments on insect infestation in paddy at monthly intervals.

FIG.3

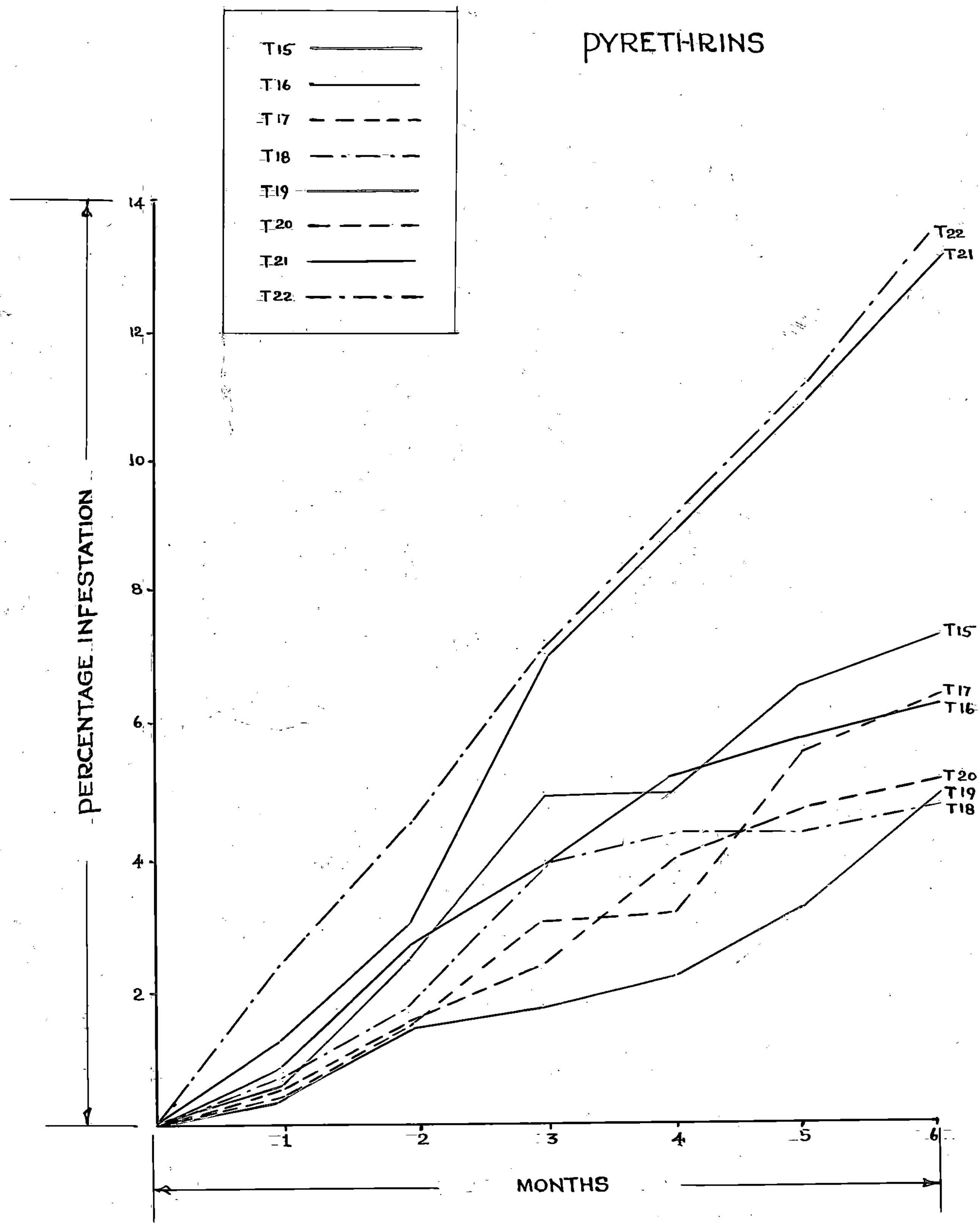

PYRETHRINS
T15
T16
T17
T18
T19
T20
T21
T22
PERCENTAGE INFESTATION
14
12
10
8
6
4
2
1
2
3
4
5
6
MONTHS

TABLE II

MEAN VALUES OF INFESTATION IN STORED PADDY UNDER PRE-TREATMENTS WITH MALATHION, LINDANE AND PYRETHRINS OBSERVED AT DIFFERENT PERIODS AFTER TREATMENTS AND STORAGE

Treatments		Number of grains damaged out of 500						
		Months after treatments						
		1	2	3	4	5	6	Total means
Malathion	T1	2.0	12.0	21.3	20.6	24.3	25.6	17.7
	T2	7.0	11.6	17.6	20.0	26.6	33.0	19.3
	T3	3.0	7.0	20.0	22.3	22.3	22.6	16.2
	T4	4.0	10.6	16.3	22.0	25.3	26.6	17.5
	T5	2.6	4.0	10.3	10.0	12.0	14.0	8.8
	T6	3.3	5.3	11.0	13.3	14.3	14.6	10.3
	T7	9.0	17.6	28.0	42.0	51.0	68.0	36.0
Lindane	T8	3.3	14.0	24.3	27.0	35.3	56.0	26.6
	T9	6.3	14.0	27.0	28.3	42.3	59.0	29.5
	T10	4.0	11.0	22.3	27.3	28.0	38.3	21.8
	T11	6.3	11.3	20.3	27.0	34.0	40.0	23.2
	T12	4.0	9.0	12.3	16.0	23.0	28.3	15.4
	T13	3.3	8.0	11.6	24.0	33.3	34.6	19.2
	T14	8.0	17.0	41.6	45.6	51.0	65.0	38.0
Pyrethrins	T15	3.0	12.6	25.0	25.0	34.0	36.6	22.7
	T16	4.0	13.3	19.6	26.0	29.0	31.3	20.5
	T17	3.0	8.0	14.6	16.0	28.6	32.0	17.0
	T18	3.6	9.0	20.0	22.0	18.6	24.0	16.2
	T19	2.0	8.0	9.0	10.6	16.6	21.6	11.3
	T20	3.0	8.6	12.0	20.6	23.6	25.6	15.6
	T21	7.0	15.0	35.6	45.0	55.0	66.3	37.3
Control	T22	12.3	23.6	36.0	46.6	56.0	68.3	40.4

applied on the grains appears to be the most effective of the treatments. But neither in malathion nor the other two insecticides applied on the bags alone do not prevent insect infestation.

The data relating to the damage of the grains under the different treatments observed at each monthly intervals have been statistically analysed also.

Table III relates to the analysis of variance of the observations made at the end of 1 month after treatment and storage.

TABLE III

Analysis of variance

Observation at the end of the 1st month after treatment
Test insecticides - Malathion, Lindane and Pyrethrins.

Source of variations	Sum of squares	Degrees of freedom	Variance	F.	F. from table at 5% level
Total	594.6	65			
Treatment	427.2	21	30.34	5.3**	1.83
Error	167.4	44	3.80		

** Significant at 5% and 1% level

Critical difference at 5% level = 3.224

Inference:

T1, T19, T4, T6, T8, T18, T13, T17, T3, T20,
T15, T16, T12, T4, T10, T9, T11, T2, T21, T14
T7, T22.

It reveals that there exists significant diff-rences among different treatments during the months. The variability was from 2(T1 and T19) to 12.3 (in Control T22).

Untreated grain stored in bags treated with the insecticides shows lower infestation than control. This difference in the infestation is significant. All other treatments are highly significant in their difference from control in relation to insect infestation. Among the treat-ments, T1 and T19 are significantly different from T9, T11, T2, T21, T14 and T7. Other treatments are not significantly different among themselves.

Table IV gives the analysis of variance of the data on the observations made at the end of 2 months after treatment and storage.

TABLE IV

Analysis of variance

Observations after two months of treatments

Source of variations	Sum of square	Degrees of freedom	Variance	F.	F from table at 5% level
Total	1733.8	65			
Treatments	1231.8	21	58.6	5.14**	1.83
Error	502.0	44	11.4		

** Significant at 5% and 1% level.

Critical difference at 5% level = 5.541.

Inference:

T5, T6, T3, T13, T19, T17, T20, T12, T18, T15, T16 —
T8, T19, T1, T7, T14, T2, T22.

It is seen that the treatments are significantly different. The range of mean values of infestation is from 4.0 (T5) to 23.6 (T22). All treatments are significantly different over control.

The treatments in which the bags alone are treated (T14, T7, T21) also are significantly different from control.

Table V gives the analysis of variance of the data on the infestation observed at the end of 3 months after storage.

TABLE V

Analysis of variance

Infestation at the end of 3rd month

Sources	Sum of squares	Degrees of freedom	Variance	F.	Table F.
Total	5798.6	65			
Treatments	4967.2	21	236.5	12.5**	1.83
Error	831.4	44	18.9		

** Significant at 5% and 1% level

Critical difference 7.15

Inference:

T19, T5, T6, T12, T20, T17, T13. T16, T8, T9 — T15, T7, T14, T21, T22

It is observed that all the treatments are significantly different. All the treatments appear superior to control except T14 and T21.

The range of variation in infestation is from 9 (T19) to 41.6 (T14).

As regards the effect of bag treatment alone malathion treatment (T7) appears significantly different from Control, while treatments with pyrethrins and lindane (T21 and T14) are not significantly different.

It is also seen that there is no significant difference between infestation in the grains treated and stored in treated bags on the one hand and the infestation in the grains treated and stored in untreated bags on the other.

Table VI gives the analysis of data relating to infestation observed at the end of four months.

TABLE VI

Analysis of variance

Infestation at the end of 4th month

Source	Sum of squares	Degrees of freedom	Variance	F.	Table F.
Total	8157.0	65			
Treatments	7287.0	21	347.0	17.6**	1.83
Error	870.0	44	19.7		

** Significantly different at 5% and 1% level.

Critical difference (0.05 level) = 7.3

Inference:

T5, T19, T6, T17, T20, T12,

T1, T2, T4, T18, T3, T8, T11, T10, T15, T16, T13, T9,

T7, T14, T21, T22

The range of variability is from 10 (T5) to 46.6 (T22).

It will be seen that there exists no significant difference among the control and the treatments in which the bags alone are treated with the insecticides. There is, however, significant variation between the different other treatments involving grain treatments on the one hand and control on the other. It is also evident that in the same level of each insecticide there is no significant variation between grains alone treated and grains and bags treated.

Table VII gives the analysis of data relating to infestation observed at the end of 5 months.

TABLE VII

Analysis of variance

Infestation after 5 months of treatment

Source	Sum of squares	Degrees of freedom	Variance	F.	Table F.
Total	41294.1	65			
Treatment	40102.1	21	1909.6	70.4**	1.83
Error	1192.1	44	27.1		

** Significant at 5% and 1% level

Critical difference - 8.543

Inference:

T5, T6, T19, T18, T3, T12, T20, T1, T4,

T2, T20, T17, T16, T13, T11, T15, T8, T9,

T7, T14, T21, T22

The overall variation in the treatments is seen to be significant. The range of mean values is from 12.0 (T5) to 56.0 (T22).

All the treatments are significantly different from control except the treatments T7, T14, T21 where the bags alone are treated.

There appears to be no significant difference between grains alone treated and grains and bag treated, in the same levels.

Between doses, significant variation is observed with malathion treatments. The treatment T5 (24 ppm. on grain and 7.8 mg. per 1120 sq. cm. of bag surface) was found significantly different from the other levels. Significant differences between higher doses and lower doses were also observed in case of pyrethrins and lindane.

There is also no significant difference between the infestation in the untreated grains stored in treated bags and control.

In Table VIII is represented the results of analysis of data on the insect infestation of grains observed 6 months after treatment and storage.

TABLE VIII

Analysis of variance

Infestation after 6 months of treatment

Source	Sum of squares	D.F.	Variation	F.	Table F.
Total	20945.8	65			
Treatment	19749.1	21	940.43	34.57**	1.83
Error	1196.7	44	27.2		

** Significant at 5% and 1% level

Critical difference (0.05) = 8.564

Inference: T5, T6, T19, T3, T13, T20, T1, T4, T12, T16

T17, T2, T13, T15, T10, T11, T8, T9, T14, T21, T7, T22

It is seen that all the treatments among themselves are significantly different. The range of infestation is 14.0 (T5) to 68.3 (T22). All treatments are also significantly different from control except T14, T7 and T21. The latter three are treatments in which the bags alone are treated with the insecticides. No significant difference in the infestation is observed between these treatments and Control.

Comparing the effect of the grains alone treated and the grains and bags treated, it is seen that there is no significant variation between the infestation in the treatments where the grain alone are treated and the infestation in the treatments wherein both the grains and the bags are treated.

Considering the different levels of each insecticide it is evident that the highest concentration is significantly more effective than the two lower concentrations under study of each insecticide.

Table IX summarises the analysis of the effect of the various treatments observed at all the six monthly intervals taken together.

TABLE IX

Analysis of variance

Effect of various treatments observed at 6 monthly intervals

Source of variations	Sum of squares.	D.F.	Variance.	F.	Table F.
Total	98767.4	395			1.96
Treatment	31708.1	21	1509.9	83.7**	
Between chemicals	3101.1	2	1550.6	86.0**	
Bag, grain and grain & bag	16586.4	2	8293.2	460.0**	
Between levels	4691.3	2	2345.6	130.0**	
Chemical Vs Control	6502.1	1	6502.1	366.2**	
Grain Vs Control	7459.6	1	7459.6	413.7**	
Month	49922.6	5	9984.5	553.7**	
Month x Treatment	12376.0	105	117.9	6.5**	
Error	4760.7	264	18.03		

** Significant at 5% and 1% level

Critical difference at 0.05 level = 6.77

It will be observed that there is significant difference in infestation in the different treatments.

Between the three insecticides, the inference is as follows:-

Treatment	Mean range during 6 months
Malathion	17.9
Pyrethrins	20.1
Lindane	24.9

Critical difference at 0.05 level is 6.77

ie. Malathion Pyrethrins Lindane

Thus malathion treatments are significantly different from lindane treatments. No significant difference is observed between malathion and pyrethrin treatments and between pyrethrin and lindane treatments.

Comparing the effectiveness of the treatment of bag alone on the one hand and the treatment of the grains only on the other, it is seen that there is significant difference between these two and that the treatments involving the grain treatments are superior to those in which the bags alone are treated.

With regard to the comparison, grain alone treated Vs. grain and bag treated, it is seen that in their effect there is no significant difference between the two for each level of the insecticides.

Between the three levels of each insecticide the comparisons were as follows:-

<u>Malathion</u>: T5 (Malathion treated grain at 24 ppm. and bag sprayed with malathion at 7.8 mg. bag surface) and T6 (Malathion treated grain at 24 ppm. and bag not treated) are significantly superior to T4 (grains treated with malathion at the rate of 16 ppm. and bag not treated), T2 (grains treated with malathion at 8 ppm.) and T1 (grains treated with malathion at 8 ppm. and bags treated at 7.8 mg. per bag surface).

<u>Pyrethrins</u>: T19 (grains treated at 4 ppm. and 0.28 mg. on bag surface) is significantly more effective than T16 (grains treated at the rate of 1 ppm. and bag not treated) and T17 (grains treated at the rate of 2 ppm. and 0.28 mg. on bag surface).

<u>Lindane</u>: T12 (grains treated with lindane at the rate of 12 ppm. and 7.8 mg. on bag surface) and T13 (grains only treated with lindane at the rate of 12 ppm.) appear significantly superior to T8 (grains treated at the rate of 4 ppm. and 7.8 mg. lindane on bag surface) and T9 (grains only treated with lindane at the rate of 4 ppm.).

All the treatments involving use of insecticides on grains are significantly different from control with regard to infestation by insects.

DISCUSSION

DISCUSSION

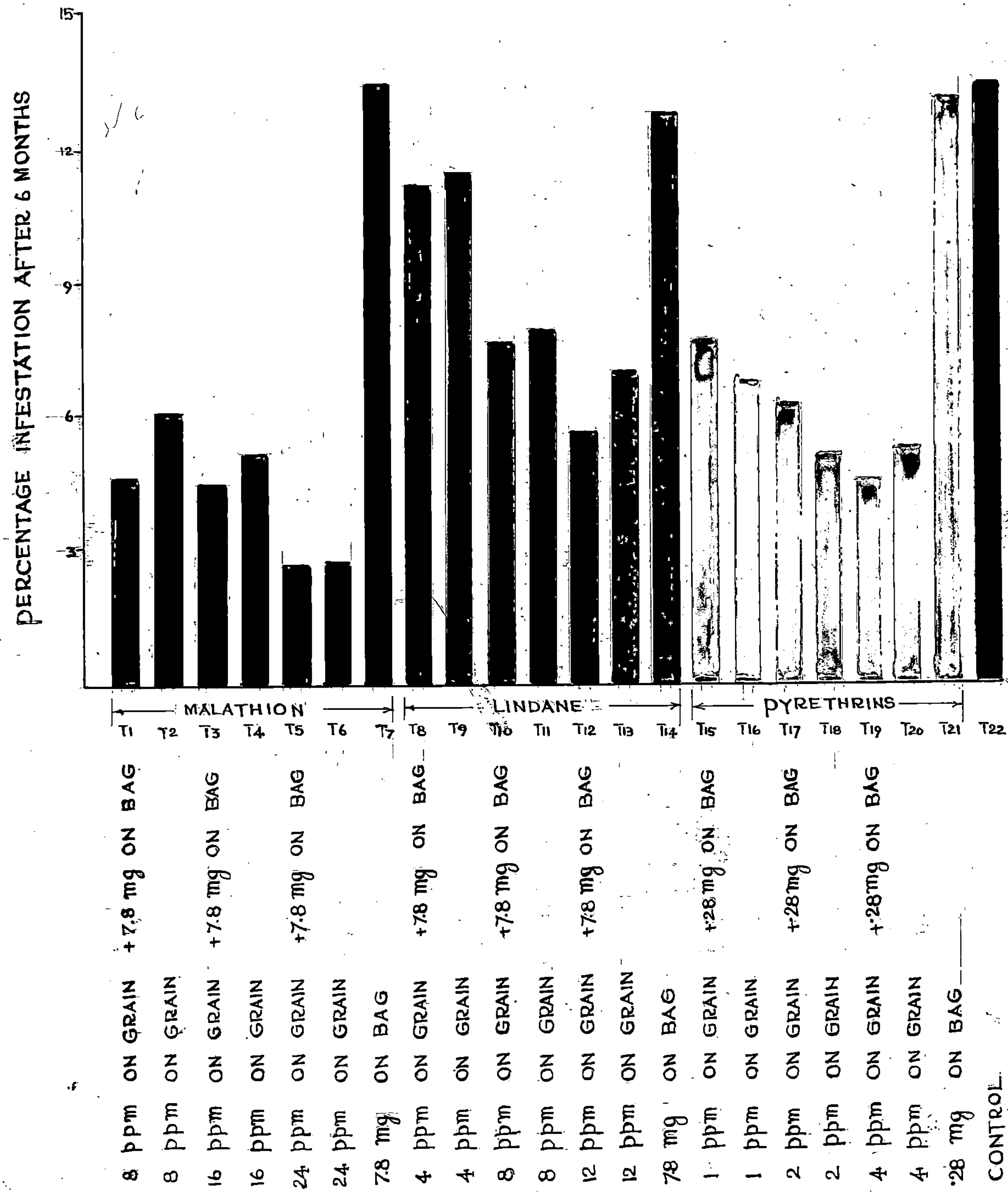
In the present studies, the effect of insecticides deposited on the external surface of unhusked paddy, in protecting the grains against insect infestations has been ascertained. The insecticides were deposited on the grain surface before being stored by spraying the grains with the insecticide emulsion and drying them. The added effect of spraying the gunny bags in preventing insect infestation was also ascertained. The three insecticides used were malathion, lindane and pyrethrins which are non-hazardous in nature. The experiment was done under godown conditions. Effect of the treatments was assessed by observing the extend of infestation in each treatment for a period of six months at monthly intervals. The results obtained are discussed below.

Relative efficacy of three insecticides in preventing insect infestation in stored rice:

Fig.4 gives an overall picture of the relative efficacy of the three different insecticides under test in preventing insect infestation in stored paddy. It is clear that the malathion treatments provided the maximum protection of the grains from damages due to insect pests, and lindane treatments the least protection. Pyrethrin

Fig.4. Consolidated diagram showing the effect of malathion, lindane and pyrethrins treatments on insect infestation in paddy at the end of 6 months after treatment and storage

FIG. 4


PERCENTAGE INFESTATION AFTER 6 MONTHS
15
12
9
6
3
MALATHION
LINDANE
PYRETHRINS
T1 T2 T3 T4 T5 T6 T7 T8 T9 T10 T11 T12 T13 T14 T15 T16 T17 T18 T19 T20 T21 T22
8 ppm ON GRAIN +7.8 mg ON BAG
8 ppm ON GRAIN
16 ppm ON GRAIN +7.8 mg ON BAG
16 ppm ON GRAIN
24 ppm ON GRAIN +7.8 mg ON BAG
24 ppm ON GRAIN
7.8 mg ON BAG
4 ppm ON GRAIN +7.8 mg ON BAG
4 ppm ON GRAIN
8 ppm ON GRAIN +7.8 mg ON BAG
8 ppm ON GRAIN
12 ppm ON GRAIN +7.8 mg ON BAG
12 ppm ON GRAIN
7.8 mg ON BAG
1 ppm ON GRAIN +·28 mg ON BAG
1 ppm ON GRAIN
2 ppm ON GRAIN +·28 mg ON BAG
2 ppm ON GRAIN
4 ppm ON GRAIN +·28 mg ON BAG
4 ppm ON GRAIN
·28 mg ON BAG
CONTROL

treatments occupied an intermediate position. Among the malathion treatments a deposit of 24 ppm. on the grain surface was found to be the most efficient in preventing insect attack. Thus this treatment showed only 2.8% infestation after 6 months of storage as against 13.7% in control. The treatment of the bag did not appear to give any significant additional effect.

Statistical analysis showed that all the insecticidal treatments were significantly effective in preventing insect damage in comparison with control. Among the insecticides, malathion treatments were found significantly superior to lindane treatments but not superior to pyrethrin treatments. These findings agree with those made by Yust (1958) who found malathion 8 ppm. superior to pyrenone and lindane in protecting stored corn from insect damage for 9 months. He also found that pyrenone and lindane gave protection for 6 months. Prevett (1959) also made similar observations to the effect that malathion was superior to lindane for the protection of stored paddy in bags.

In both the above said cases, however, the stored grains were admixed with the dusts of the insecticides. In the present investigation, the grains were sprayed with emulsion of the insecticides and dried before being stored. This method of application was considered more advantageous than mixing with dust formulations. The usual processes involved after harvest and before final storage of rice, are threshing, cleaning and drying. The process of drying takes 3 to 4 days. The insecticidal spray can be applied on these grains very conveniently while being dried and if the spraying can be done during the last lap of drying, minimum loss of insecticide deposit on the grains can be ensured. This method of application is considered better than the so called"pre-harvest prophyllaxis" recommended by Majumder et al (1961) wherein pre-harvest application of malathion spray is envisaged to control insect infestation in stored wheat. In this method since the grains are subjected to various processes such as threshing, cleaning and drying before being stored, there is the possibility of a major portion of the insecticide deposit being lost. The method adopted in the present investigation thus appears to have eliminated all the disadvantages mentioned above. Results of these investigations however have confirmed that among non-hazardous insecticides malathion is the best for protecting stored paddy. Canada and U.S.A. have set a tolerence limit of 8 parts per million for malathion in a stored product. A deposit of 24 ppm. of malathion was found effective in protecting paddy in storage for 6 months in the present studies. It may be pointed out that this deposit is on the surface of the husk only and that this will get eliminated during the subsequent processes of par-boiling, drying and milling. Thus there is absolutely no risk of any toxic hazard due to the application of the insecticide in the manner adopted in the present studies.

Effect of treating the bags with the insecticides:

Comparing the effect of treating the gunny bags in preventing insect infestation with that of control it was observed that bags treated with pyrethrins at 0.28 mg. and lindane at 7.8 mg. per 1120 sq. cms. bag surface, protected the grain from insect attack only for a period of two months. The effects of these treatments were lost subsequently. In the case of malathion treatment of the bag it was found that the treated bags gave protection to the stored paddy for a period of three months, the effect being lost thereafter. So the treatments of bag alone with any of these insecticides, in the concentrations tried, did not appear effective in protecting stored paddy for prolonged periods.

As regards the added effect obtained by the treatment of bags in addition to the treatment of the grains, it was observed that though the treatments of the bag reduced insect infestation to some extent, this reduction was not statistically significant. As such, the additional treatment of the bags did not appear to be of any advantage. These findings are in line with those of some previous workers. Thus, Pingale (1954) found that pyrethrins at 5 to 30 mg. per sq. ft. of bag was effective only for 2 months. It was also found that malathion 50 E.C. at 1:300 with water sprayed at 3 litres per 100 sq. meter surface remained effective only for 3 weeks (Lallan Rai 1963).

<u>Over-all conclusions:</u>

From the discussion of the results given above the following conclusions can be drawn.

(1) Pre-treatment of paddy grains involving spraying the insecticide emulsion on them and drying before being stored is a suitable method to prevent insect infestation in stored paddy up to a period of 6 months.

(2) Among the three insecticides, namely malathion, pyrethrins and lindane, malathion and pyrethrin (Pyrethrins and Piperonyl butoxide 1:10) are significantly superior to lindane in protecting stored paddy from insect infestation. Malathion at 24 parts per million of the grain gives the maximum protection.

(3) Treatment of bags with lindane or pyrethrins give protection to stored paddy only for 2 months while malathion treatment gives protection for 3 months.

(4) There is no added advantage in treating the bags in addition to treating the grains with the insecticides.

(5) Malathion at 24 parts per million can be recommended as a pre-storage spray for preventing insect infestation in stored paddy by virtue of its high protective capacity and its low mammalian toxicity.

SUMMARY

SUMMARY

An experiment was conducted under godown conditions to find out the effect of pre-storage treatment of paddy grains (PTB 10) with three doses each of malathion, pyrethrin and lindane in controlling insect infestations in stored paddy. The different doses of the three insecticides used were malathion 8, 16 and 24 ppm., pyrethrins 1, 2 and 4 ppm., and lindane 4, 8 and 12 ppm. The grains were sprayed with the insecticide emulsions, dried and exposed to infestation in an infested godown.

Effect of treating the bags with the insecticides in preventing insect infestations in paddy stored within the bags, was also ascertained by spraying the bag with each of these insecticides so as to give deposits of 7.8 mg. of lindane and malathion and 0.28 mg. of pyrethrin per 1120 sq. cm. of bag surface.

Malathion was found to be the most effective insecticide in preventing insect infestation in paddy, followed in the descending order by pyrethrins and lindane. Among the three doses of each insecticide, the highest doses, namely malathion 24 ppm., pyrethrin 4 ppm. and lindane 12 ppm. were significantly superior to the

lower concentrations of the respective insecticides.

The deposits of the insecticides applied on the bags remained effective in preventing insect infestation in paddy stored within those bags, for 2 months in the case of pyrethrins and lindane and for three months in the case of malathion.

Treatment of the bag with the insecticides, in addition to the treatment of the grains, did not appear to be of any significant advantage in preventing insect damage to the stored paddy grains.

The advantages of pre-storage treatment of paddy grains with insecticides have been discussed.

It has been concluded that pre-storage treatment of paddy grains with malathion at 24 ppm. of the grains is a suitable method for protecting stored paddy from insect infestations.

Literature on the prevention and control of insect infestation in stored rice have been reviewed.

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APPENDICES

APPENDIX I

INFESTATION IN STORED PADDY PRE-TREATED WITH MALATHION, LINDANE AND PYRETHRINS OBSERVED AT DIFFERENT PERIOD AFTER TREATMENTS

Treatments		Number of grains damaged out 500																	
		Months after treatment																	
		1			2			3			4			5			6		
		RI	RII	RIII	RI	RII	RIII	RI	RII	RIII	RI	RII	RIII	RI	RII	RIII	RI	RII	RIII
Malathion	T1	3	2	1	17	9	10	18	20	16	21	20	21	29	18	26	24	29	24
	T2	6	7	8	12	13	10	20	13	20	18	21	21	26	28	26	38	31	30
	T3	1	4	4	8	7	6	20	22	18	21	25	21	23	25	19	25	19	24
	T4	6	2	4	10	12	10	16	18	15	25	24	17	25	25	26	30	24	26
	T5	1	4	3	1	6	5	10	11	10	13	9	8	15	10	11	15	11	16
	T6	1	4	5	5	5	6	11	12	10	12	14	14	15	12	16	13	16	15
	T7	9	11	7	19	16	18	28	26	30	42	40	44	56	48	49	65	70	69
Lindane	T8	2	3	5	13	15	14	30	22	21	24	30	27	36	38	32	50	56	62
	T9	7	6	6	18	11	13	33	28	20	32	26	27	58	33	36	48	58	71
	T10	2	6	4	8	9	16	25	20	22	24	28	30	30	23	31	43	40	32
	T11	6	7	6	13	15	6	19	20	22	25	32	34	36	36	30	42	38	40
	T12	4	3	5	5	10	12	15	9	13	20	16	12	20	29	20	23	32	30
	T13	1	5	4	10	9	5	15	10	10	21	30	21	32	38	30	36	36	32
	T14	5	9	10	12	20	19	38	45	42	40	52	45	49	50	54	59	70	66

Contd......

APPENDIX I Contd.

		1			2			3			4			5			6		
Pyrethrins	T15	4	2	3	14	11	13	29	26	20	33	22	20	40	36	26	31	44	35
	T16	5	2	5	14	10	16	27	15	17	30	21	27	30	27	30	29	27	38
	T17	5	3	1	8	9	7	20	10	14	22	12	14	30	29	27	31	33	32
	T18	1	4	6	13	6	8	28	13	19	26	20	20	17	24	15	20	32	20
	T19	1	3	2	10	6	8	13	10	4	5	18	9	20	13	17	30	20	15
	T20	2	3	4	8	9	9	6	20	10	19	27	16	19	34	18	26	30	21
	T21	5	8	8	9	20	16	30	41	36	41	50	44	58	61	46	68	70	61
Control	T22	16	11	10	27	23	20	35	40	33	42	56	42	56	59	53	75	68	62

APPENDIX II

LIST OF PESTS OF STORED RICE

ORDER COLEOPTERA

1.	*Sitophilus oryzae* Linn	Curculionidae
2.	*Rhizopertha dominica* Fab.	Bostrychidae
3.	*Dinoderus minutum* F.	Bostrychidae
4.	*Trogoderma ganarium*	Dermestidae
5.	*Attagenus* sp.	,,
6.	*Lasioderma serricorne* F.	,,
7.	*Orysaeophilus surinamensis* Linn	Cucujidae
8.	*Laemophloeus* spp.	,,
9.	*Ahasvera advena* W.	,,
10.	*Cathartus quadricollis* Gue	,,
11.	*Tenebroides mauritanicus* Linn	Tenebrionidae
12.	*Tenebrio obscuris* Linn	,,
13.	*Tribolium* spp.	,,
14.	*Palorus* spp.	,,
15.	*Latheticus oryzae* Wat.	,,
16.	*Alphitobius* spp.	,,
17.	*Necrobia rufipes*	Cleridae
18.	*Carpophilus* spp.	Nitidulidae
19.	*Lophocateres pusillus* K.	,,
20.	*Thorictodes heydini*	Thorictidae
21.	*Ptinus tectus*	Ptinidae

ORDER LEPIDOPTERA

22.	Sitotroga cerealella Oliv.	Gelechiidae
23.	Epithectis studiosa Meyr.	,,
24.	Aristotelia austeropa M.	,,
25.	Ephestia spp.	Phycitidae
26.	Plodia interpunctella Hub.	,,
27.	Corcyra cephalonica Staint	Galleriidae
28.	Tinea granella C.	Tineidae
29.	Setomorpha rutella Zell.	,,
30.	Erechthias zebrina But.	Lyonetiidae
31.	Ampera intrusa Dist.	Lygaeidae, Hemiptera

ORDER ACARINA

32.	Tyroglyphus farinae	Tyroglyphidae
33.	Chrotoglyphus arcuatus	

APPENDIX III

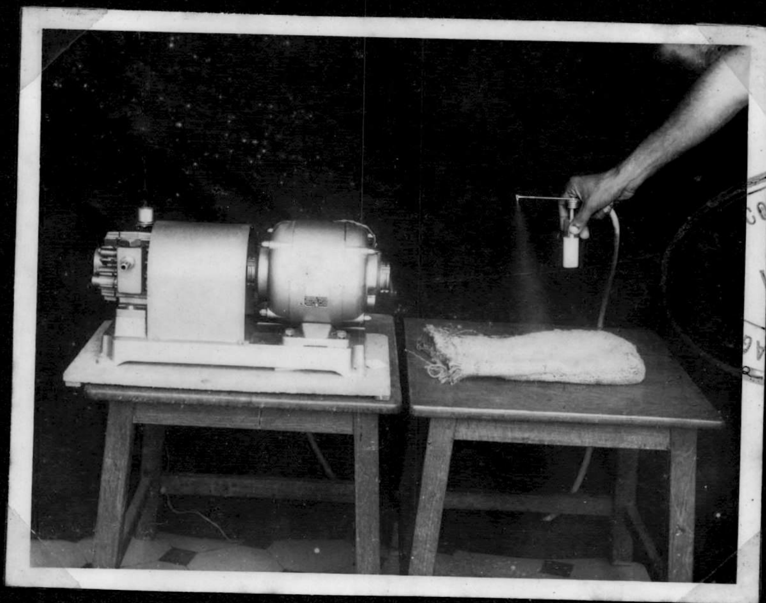
RECORD OF TEMPERATURE AND HUMIDITY (OCTOBER, 1964 - MAY, 1965)

Month	Weeks	Maximum temperature		Minimum temperature		Humidity	
		From	to	From	to	From	to
October	1	81	82	73	79	67	86
	2	80	83	76	78	77	90
	3	80	81	76	77	77	83
	4	80	81	76	78	80	90
November	1	80	81	74	78	85	90
	2	81	81	74	76	85	90
	3	81	81	76	76	85	91
	4	81	82	78	78	80	86
December	1	81	82	76	78	83	87
	2	82	83	76	78	91	92
	3	81	82	74	76	86	91
	4	82	83	74	76	87	91
January	1	81	83	76	78	83	91
	2	82	83	76	78	83	87
	3	81	82	76	78	86	90
	4	81	83	76	78	85	90
February	1	81	82	78	78	86	94
	2	81	82	74	78	83	92
	3	83	84	78	80	80	84
	4	83	84	78	80	80	84
March	1	83	84	76	78	86	90
	2	83	84	76	78	86	91
	3	86	88	78	80	86	91
	4	82	84	78	80	84	91
April	1	86	88	80	82	90	94
	2	86	90	80	82	91	96
	3	86	90	80	82	90	96
	4	86	90	80	82	92	96
May	1	84	86	78	80	92	95
	2	86	90	78	80	89	96

FIGURES

Fig. 5. Photograph showing the treatment of the bags with insecticides by atomiser and compression pump.

Fig. 6. Photograph showing the treatment of the grains with insecticides.



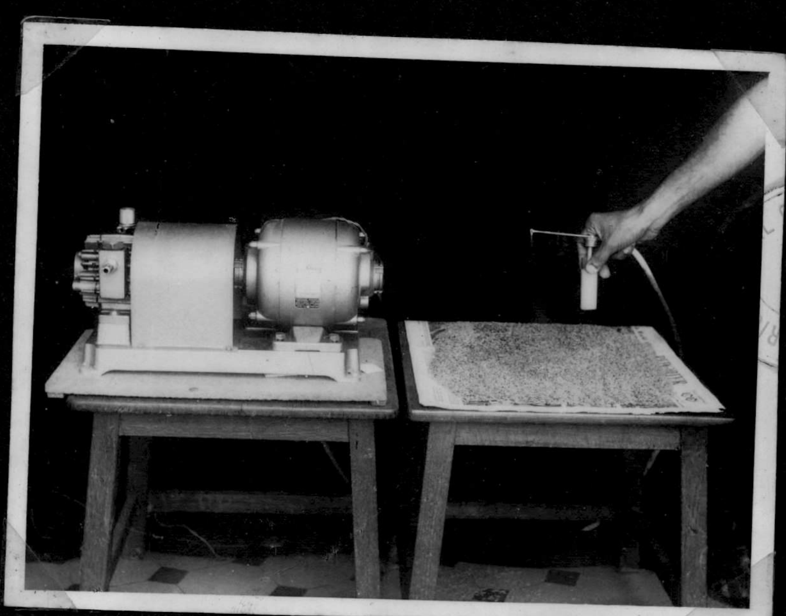
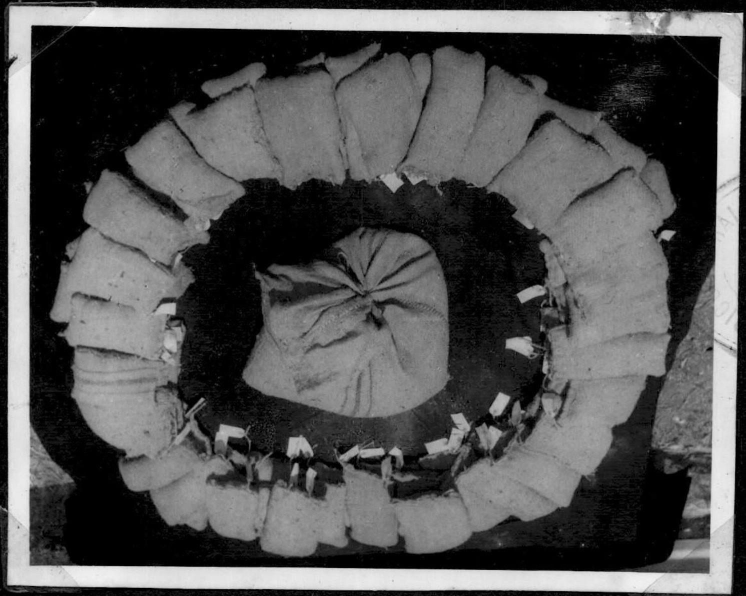


Fig.7a. Photograph showing the arrangements of the treated bags in the godown with a bulk culture bag in the middle of the treated bags.

b. A treated bag seperately.



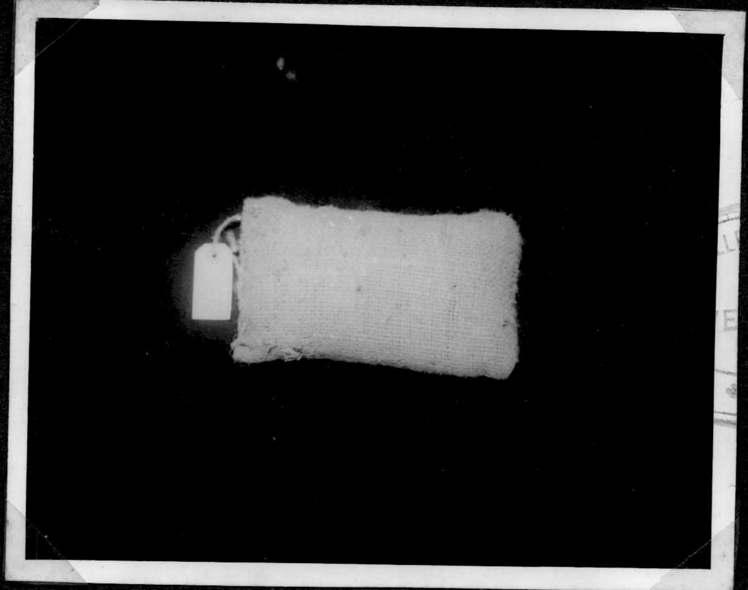


Fig.8. Photographs showing the arrangements of samples of treated grains in specimen tubes on the tube stand in the laboratory.