INVESTIGATIONS ON THE CONTROL OF THE KHAPRA BEETLE, *TROGODERMA GRANARIUM*, EVERTS) WITH CALCIUM CYANIDE.

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The khapra beetle, *Trogoderma granarium*, Everts 1898, has been referred to in ecent years as *Trogoderma khapra*, Arrow, and *Attagenus undulatus*, Mot. Investigations on the pest have been carried out by Barnes & Grove (1) in India, and by Dendy & Elkington (2), Mason (3), Parker & Long (4), and Morison (5) in England.

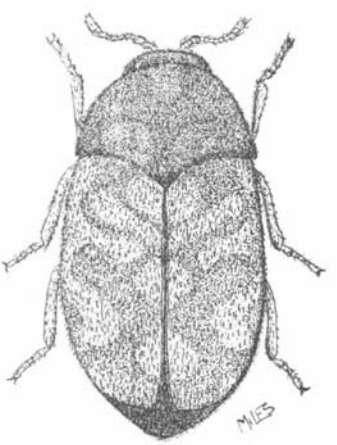

Fig. 1. *Trogoderma granarium*, Everts × 17.

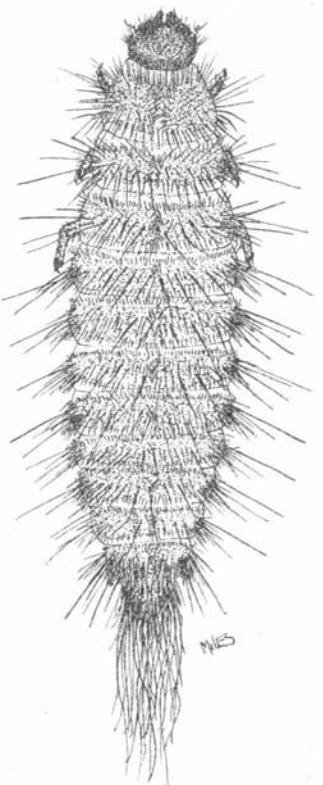

Fig. 2. *T. granarium*, larva × 17.

The most exhaustive work on the khapra beetle is that carried out by Voelkel (6) n Germany. This investigator gives a full account of the life-history of the pest and a detailed description of the different stages; he also includes an account of experiments on control by means of trapping and fumigation, and concludes that, as with other pests of stored products, the use of toxic gases promises the best results. In his experiments Voelkel used hydrocyanic acid gas, chlorpicrin and tetrachlorethane, all of which proved toxic to both adults and larvae.

During the Great War large quantities of Indian barley were shipped to the British Isles and this grain appears to have been infested with various stages of the khapra beetle. When the barley passed through the early processes in the making of malt, little notice was taken of the presence of the insect; but later it was found that the malt in the storage bins was infested with the pest, which had developed rapidly in the higher temperatures of the bins, whereas little development had taken place in the barley stores. Arrow (7) in 1917 evidently thought that it was not likely that the khapra beetle would become established as a pest in England, presumably because of the adverse temperature conditions; but apparently the infestation of the malt bins, which offer to the insect highly suitable conditions for rapid development had not been foreseen.

A considerable number of malt bins are now infested with khapra, and although little Indian barley is used, the pest still breeds in the malt bins and is responsible for an annual loss to the maltsters. Towards the end of the war and for a few years after, chlorpicrin, which was comparatively cheap and easily available, was used for malt bin fumigation. Though this treatment afforded great relief, the pest was not eradicated; and owing to the lack of further supplies of this gas, little control treatment has been carried out during the last three or four years, with the result that the pest has been increasing without any other check than that occasioned by the thorough cleaning of the bins in the summer when the last malt is drawn off. Such cleaning is only superficial, for though all dust, cast khapra skins and other débris are swept from the ceilings, walls and floors, the immature larvae are not removed from the deeper crevices.

Laboratory Experiments with Calcium Cyanide.

In order to determine whether hydrocyanic acid gas derived from calcium cyanide would prove toxic to the larvae of khapra beetles, an air-tight fumigating chamber was constructed. This glass and wood chamber had a cubic capacity of 5½ cubic feet, and was placed on a bench in the laboratory. Khapra larvae were placed in a glass basin on the floor of the chamber and provided with corrugated paper, in the folds of which they quickly secreted themselves. A wet and dry bulb thermometer was also introduced into the chamber, and the calcium cyanide was placed as evenly as possible on the floor round the basin. Fumigations were conducted with a temperature range of 67–72° F., and a relative humidity of 76–85 per cent., and exposures varying from 19½ to 24 hours. The calcium cyanide used throughout the experiments was "Cyanogas" brand, "G" grade, guaranteed to contain 40 to 50 per cent. pure calcium cyanide. The initial dosage was 10 oz. per 1,000 cubic feet and resulted in 13·8 per cent. kill. The dosage was then increased to 15 oz. per 1,000 cubic feet, and following this fumigation all the larvae were inactive next day, but numbers gradually revived. Fourteen days after the fumigation 45·45 per cent. were dead, 31·9 per cent. had recovered, and the remaining 22·72 per cent. were classed as doubtful.

Since all the larvae appeared lifeless for some time after fumigation with calcium cyanide at the rate of 15 oz. per 1,000 cubic feet, a dosage of 12½ oz. per 1,000 cubic feet was used in several fumigations, the humidity being increased to 85 per cent., since there was an indication that with higher humidity a greater kill might be obtained. The results from the fumigations indicated a kill of 88–92 per cent. after an exposure of 19–24 hours.

Upon examination immediately after exposure to the hydrocyanic acid gas the larvae used in these experiments were inactive and apparently lifeless. Within an hour or so odd specimens became active and when placed near food readily resumed

feeding. In the course of a day or two larvae which had been killed by the gas were easily distinguished because of shrivelling and discolouration. The remainder appeared healthy but incapable of movement. In from three to six days those larvae which had not received a toxic dose usually recovered, but occasional specimens recovered after as long as from 14 to 26 days. With larvae which had received a toxic dose this prolonged state of inactivity gradually merged into death.

The state of inactivity and apparent lifelessness of the larvae after fumigation is interesting, and two explanations are offered. It may be that the larvae can pass into a resting state similar to that produced by lack of oxygen (1), in which they remain healthy for a considerable time. The second explanation is that the hydrocyanic acid gas induces paralysis of the nervous system of the khapra larvae, as it is known to do with other insects. The larvae are to all intents and purposes healthy, but incapable of movement. Raising the temperature produced traces of movement after a few days, and in some cases movements were produced for the first time fourteen days after fumigation, and the larvae finally recovered and resumed feeding. Where fumigation is sufficiently strong and prolonged, the coma gradually merges into death.

In the first part of the accompanying table a summary is given of the data obtained from the laboratory fumigations.

Malt Bin Fumigations.

Based on the results of the laboratory experiments, three fumigations, commencing in September 1926, were conducted in commercial malt bins. The bins were approximately square with a capacity of about 5,000 cubic feet. Each had two walls faced with pitch, and two walls of woodwork which gave the pest access to the adjoining bins through cracks and spaces between the boards. Before fumigating all these cracks were carefully pasted over with thick brown paper.

The initial dose of calcium cyanide was 1 lb. per 1,000 cubic feet, but the dosage was subsequently increased to 1¼ lb. and finally to 2 lb. per 1,000 cubic feet as the temperature and relative humidity of the bins decreased. The fumigations were commenced about mid-day and the bins sealed up until about a week later, when they were thoroughly ventilated before being entered to examine the results and collect larvae.

The temperatures during the period occupied by the fumigations varied from 69° F. to 58° F., and the relative humidity from 69 per cent. to 61 per cent. Though these temperatures have proved satisfactory for glasshouse fumigation, with such low relative humidity as persisted in the malt bins the rate of evolution of hydrogenic cyanide is so slow as to render it difficult to obtain a concentration of hydrocyanic acid gas for a sufficient length of time to prove fatal to khapra larvae other than those exposed on the surface of the walls or in shallow crevices. This difficulty is reflected in the figures indicating the percentage of larvae killed. When the first fumigation was conducted conditions of temperature and relative humidity were at their best and the majority of larvae were in superficial positions or shallow crevices. Though the dosage was increased, subsequent fumigations yielded lower percentages of larvae killed. After the second fumigation larvae at the surface were difficult to find, but 46 were collected and all were dead. At the time of the third fumigation practically all the larvae were found in deep crevices, some over ten inches below the surface.

The gradual decrease in the numbers of larvae in surface crevices was due to two causes : the killing of many with the hydrocyanic acid gas, and the penetration of the remainder into deep crevices and fissures in the walls.

In the second part of the accompanying table a summary of the bin fumigations is given. When the conditions were most satisfactory 95 per cent. kill of the exposed larvae was obtained, which compares very favourably with the results obtained in the laboratory. With less favourable conditions, even though the dosage was increased, only 68·8 per cent. and 48 per cent. kills were obtained, the position of the larvae in the wall crevices undoubtedly influencing these results.

Conclusions and Recommendations.

Calcium cyanide can be used as a fumigant for the destruction of khapra beetles in malt bins, and at a dosage of 2 lb. per 1,000 cubic feet will give over 90 per cent. kill of exposed larvae, and a fair control of the more deeply secreted insects. The most successful results will probably be secured when several fumigations are carried out in summer as soon as possible after the malt has been drawn off. The bins should be made as air-tight as possible, and the calcium cyanide scattered evenly over the floors, the bins being finally closed and left for about a week before ventilating. Owing to the small man-holes, often in the ceilings, and inadequate ventilation and light in the older type of malt bin, the fumigation should be carried out under the supervision of a skilled and responsible fumigator, when, if used as described herein, calcium cyanide will be found to give a very satisfactory control of both adults and immature stages of the khapra beetle.

References.

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5. Morison (1925). Proc. R.Phys.Soc., Edinburgh, xxi, p. 10.
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Summary of Fumigations for the Control of Khapra Beetle.

1. *Laboratory Tests.*

Expt. No.	Date.	Dosage per 1,000 cu. ft.	Commencement of Fumigation.		Period of Fumigation.	Conclusion of Fumigation.		Date of final examination.	Dead.	Alive.	Total.	Kill.	Remarks.
			Temperature.	Humidity.		Temperature.	Humidity.						
		oz.		Per cent.	Hours.		Per cent.					P. ct.	
1	10.viii.26	10	68° F.	76	19½	67° F.	80	12.viii.26	5	31	36	13·88	Recovery apparent within 2 days.
2	11.viii.26	15	67° F.	76	20	68° F.	76	8.ix.26	14	8	22	63·63	Recovery not apparent within 3 days, noted after 14 and 26 days.
3	12.viii.26	12½	67° F.	80	19	67° F.	80	8.ix.26	34	2	36	88·8	Recovery not apparent within 2–3 days.
4	23.viii.26	12½	67° F.	80	22	72° F.	82	3.ix.26	14	2	16	87·5	
5	26.viii.26	12½	68° F.	85	24	66° F.	85	6.ix.26	26	2	28	92·8	
6	1.ix.26	16	67° F.	80	24	66° F.	83	9.ix.26	27	1	28	96·4	Greater proportion of young larvae in this batch and these show signs of death quicker than other specimens.

2. *Fumigation of Bins.*

Expt. No.	Date.	Dosage per 1,000 cu. ft.	Commencement of Fumigation.		Period of Exposure.	Conclusion of Fumigation.		Date of final examination.	Dead.	Alive.	Total.	Kill.	Remarks.
			Temperature.	Rel. Humidity.		Temperature.	Rel. Humidity.						
		lb.		Per cent.	Days.		Per cent.					P. ct.	
1	7.ix.26	1	69° F.	69	6	68° F.	72	28.ix.26	211	10	221	95	Majority of larvae from superficial crevices, etc.
2	5.x.26	1¼	69° F.	61	7	69° F.	61	19.x.26	199	90	289	68·8	Superficial larvae (46) collected separately, all dead.
3	10.xi.26	2	58° F.	63	7	51° F.	63	24.xi.26	36	39	75	48	Few superficial larvae to be found. Majority of larvae in deeper cracks and crevices.