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Control of the "Greyback" Cane Grub Pest, *Dermolepida albohirtum* Waterh., by Means of "Gammexane" (Benzene Hexachloride)*

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SUMMARY

Following the initial successful testing of "Gammexane" against cane grubs in Queensland in 1945, experimental work was undertaken to determine the effect of seasonal and soil conditions and time and method of application on the efficacy of the treatment, the minimum effective dose, and the phytotoxicity of the material.

No toxic effects on sugar cane or Poona cowpea were observed with applications of normal amounts of "Gammexane." There was slight stunting of plant cane with an application of 1,000 lb. of 10% dust per acre, but 600 lb. produced no deleterious effect on ratoon cane.

Band application of various amounts is more effective than the broadcasting of corresponding quantities.

Satisfactory control of grubs is secured if application of "Gammexane" is made prior to or during beetle flight.

A dressing of 100 lb. of 10% dust to either a plant or a ratoon crop provides adequate control of infestations. A lower amount may prove satisfactory for moderate infestations on heavier soil types, but at least 75 lb. should be applied.

Where the amount of "Gammexane" applied is sufficient for only one crop, or where ratooning operations involve removal of the insecticide from the vicinity of the stools, a "booster" treatment of 50 lb. after ratooning is effective in restoring the efficacy of an original dressing of less than 100 lb.

The single treatment for either a plant or a ratoon crop, or the practice of making an initial and a "booster" application, may profitably be replaced by a single application to the plant crop of 150 lb. of 10% dust, which provides protection for the plant and two ratoon crops. The amount may be reduced to 125 lb. where only one ratoon crop is harvested.

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* The benzene hexachloride preparation bearing the trade name "Gammexane" was the only BHC product available to Queensland canegrowers until the middle of 1949. As all the results recorded in this paper were secured with this product and as it is common usage to refer to BHC as "Gammexane" in the Queensland sugar industry, the name is used throughout the paper.

INTRODUCTION

The history of cane growing in Queensland contains many accounts of extensive crop destruction in certain districts due to the depredations of " white grubs." These are the larvae of several native Scarabaeid beetles, but the species responsible for the greatest crop losses from Mackay northwards is the " greyback " cockchafer, *Dermolepida albohirtum* Waterh., undoubtedly one of the worst pests with which any cane-growing country has had to contend. The occurrence, life-history, habits, parasite complex and economic importance of this insect were investigated more or less concurrently by Illingsworth and Dodd (1921) and Jarvis (1927). Later workers devoted their efforts to improving methods of control, and the approach was made along both biological and chemical lines. So that the problems associated with the control of this pest may be appreciated, its life history and habits will be briefly described, and some of the measures that were previously employed in attempts to restrict its activities will be outlined before proceeding to a discussion of control by means of " Gammexane."

LIFE HISTORY AND HABITS OF THE " GREYBACK " BEETLE

The beetles are usually first seen on the wing at dusk, generally between October and December, but sometimes into January. Their emergence during this period is governed chiefly by the occurrence of a substantial fall of rain (usually at least two inches), sufficient to moisten the soil and allow them to burrow upwards to the surface. On emergence, they fly to adjacent rain forest or eucalypt forest, where they feed on eucalypts, figs, palms, etc., and where mating takes place. After a period of about two weeks, a flight is made to the canefields, where the beetles re-enter the soil and deposit their eggs at depths of nine to 18 inches, each female laying approximately 28 eggs. Under ordinary moist soil conditions, incubation proceeds normally and within two weeks the small grubs are hatched. There are three grub stages, all of which are similar in appearance though differing greatly in size. The first stage lasts for approximately one month, the second for five weeks, and the third for six or seven months. The last two or three months of the third larval period are spent in a more or less inactive pre-pupal condition, after the large third-stage grubs have fed voraciously for three or four months on cane roots and on the underground portion of the stalks. When fully grown, they measure slightly more than two inches in length on being fully extended and about $\frac{3}{8}$ inch in thickness. Pupation takes place about September in earthen cells at an average depth of 14 inches, and in these the pupae eventually transform to beetles a month later. Thus, the entire cycle occupies a period of about one year.

Though the beetles have sometimes been known to feed on cane leaves for a limited period, it is the larval stage that is solely responsible for the serious damage inflicted on cane crops. The newly hatched grubs ingest quantities of soil and in the early period of their development derive a considerable amount of nourishment from the organic matter contained therein. As they gradually work their way upwards, they contact the cane roots near the surface and commence to feed on them. There they continue to feed so long as weather conditions remain favourable, but, should the surface soil dry out, they burrow more deeply and feed where there is adequate moisture. They follow the cane roots towards the rows, and by the time they have entered the second and third larval stages most of the grubs have concentrated around the base of the stools. This concentration usually occurs in February or March, and from then until May or June the grubs become increasingly destructive. Grub-infested cane first looks as though affected by drought, with an initial yellowing of the leaves and drooping of the inner spindle ; later there is death of the leaves and consequent deterioration of the maturing stalks. In extreme

Figure 1.
A crop of plant cane in the Mulgrave area showing extensive damage and uprooting of stools due to grubs.

cases the whole stool is deprived of its roots, loses its anchorage and is readily levered out of the ground by its own weight (Figs. 1 and 2). On dry red-soil areas one grub per stool is sufficient to inflict serious damage ; on some rich alluvial soils, three or four grubs can be present under a stool of cane without causing any obvious ill-effects. During periods of heavy infestations, grub populations of between 10 and 20 per stool are commonly encountered.

AREAS LIABLE TO INFESTATION

Infestations within a particular district usually coincide broadly with areas damaged in earlier outbreak years, and in these areas the more advanced crops with dense foliage usually become the more heavily infested. It is possible, therefore, to forecast pest incidence with a reasonable degree of accuracy providing certain other factors are taken into consideration. These include the possibility of dry conditions occurring during the critical period between beetle emergence and hatching of the eggs, when loss of soil moisture may reduce pest populations to harmless levels. In the wetter areas such dry periods are unlikely and cannot be relied on to affect the pest appreciably.

Figure 2.

A crop of ratoon cane in the Mulgrave area that was flattened and destroyed by grub attack. (The cane in the foreground was cut and used as planting material in an attempt to recoup some of the loss.)

Information concerning farms likely to become infested has been obtained in surveys of grub damage conducted annually since 1934 in cane areas from Tully to Cairns. As a result of these surveys a clear picture has been secured of the areas liable to damage as well as those uninfested, and they have been classified into the following four categories :—

(a) Areas in which no infestations have been recorded.

(b) Lightly infested areas showing no appreciable damage.

(c) Moderately infested areas showing some damage but no appreciable uprooting of stools.

(d) Heavily infested areas showing severe damage and considerable uprooting of stools necessitating a plough-out.

On the accompanying map have been plotted the location of possible centres of grub infestation and the severest degree of damage encountered on each individual farm in the Mulgrave and Babinda mill areas. The former area has suffered severe grub infestations on many occasions, while the latter usually suffers very little damage. Similar details are available concerning areas liable to infestation in other mill areas and, having due regard to these and to the information available regarding local beetle and grub populations, growers can be advised whether or not their fields are likely to become grub-infested. The anticipation of infestation, therefore, was the essential background in some of the investigations subsequently undertaken with "Gammexane."

EARLY CONTROL MEASURES

In early attempts to control the pest, payments were made for the collection of grubs and beetles in many districts, but effective results were not obtained. Late planting allowed some fields to escape infestation, but the lower yield obtained did not render this practice attractive. The use of varieties capable of regenerating their roots rapidly has been advocated as a means of lessening the impact of grub attack but, where dense populations are involved, the limits of varietal resistance are often exceeded and the crop collapses. In the past, some fertile cane properties were allowed to revert to forest or to grass simply because successive infestations had been so consistently heavy that cane could not be grown there without considerable expenditure on control measures. Though for a number of years soil fumigation with carbon bisulphide had proved the most satisfactory method of control, various mixtures of this chemical with the dichlorbenzenes were introduced in an attempt to improve results under adverse soil conditions. Knust (1934) described the work entailed in a soil-fumigation campaign in North Queensland, pointing out that the operation needed constant supervision. It was never a popular undertaking and soil fumigation made little headway (Table 1), for even during

Table 1

SHOWING ACRES FUMIGATED, ACRES DAMAGED, AND TONS OF CANE DESTROYED IN THE AREA FROM TULLY TO CAIRNS, 1940-1948.

Year	Acres Fumigated	Acres Damaged	Est. Loss in Tons of Cane
1940	1,900	Not available	Not available
1941	1,570	4,000	,, ,,
1942	870	5,370	,, ,,
1943	840	9,140	67,000
1944	1,183	5,000	30,000
1945	900	4,900	32,000
1946	1,514	13,000	105,000
1947	434*	2,090	7,250
1948	137*	4,500	14,000

* "Gammexane" was supplanting carbon bisulphide during these years.

1946, a year of heavy infestations, only a little over 1,500 acres were fumigated in the far north of Queensland out of a total of 13,000 acres damaged, entailing a loss of approximately 105,000 tons of cane. Even in the pre-war years when there was no labour shortage the area fumigated never exceeded 2,000 acres in any one year.

The main factors militating against the widespread use of carbon bisulphide for grub control in Queensland canefields were as follows :—

(a) Cost of treatment with this fumigant is relatively high. In pre-war years costs were seldom below £8 an acre and they frequently exceeded £10.

(b) The risk of explosion of the chemical entailed special precautions during transport, storage and use.

(c) Its high volatility limited the duration and range of its killing effects after injection into the soil. Hence, it was of little value where two or more successive beetle flights were involved.

(d) Successful control when soil conditions were below optimum—i.e., too wet or too dry—was uncertain.

(e) The work had to be carried out during periodical breaks of fine weather between monsoonal downpours.

(f) It was difficult to attract and keep suitable labour for this class of work, which is unpleasant in nature.

(g) The work is slow and there is a risk of damage occurring before its completion. Normally one man is capable of fumigating about half an acre a day.

Because of these drawbacks, soil fumigation had little appeal to growers, field workers or supervisors of Cane Pest and Disease Control Boards, the three parties most interested in pest suppression.

Various materials were tested over a period of years as alternatives to carbon bisulphide, but until the advent of the benzene hexachloride preparation marketed as "Gammexane" none proved satisfactory.

EXPERIMENTS WITH "GAMMEXANE"

In the initial test of "Gammexane" against cane grubs (Mungomery, 1945), complete control was obtained in plots treated at the rate of 100 lb. of 10% dust (1.3% gamma isomer) per acre. This test was so outstanding that provisional recommendations were made to enable growers to take full advantage of it right from the outset, and field experimental work then proceeded concurrently with farmer usage of the insecticide. Cane Pest and Disease Control Boards co-operated with the Bureau by arranging with farmers to leave untreated strips in their treated fields so that additional data could be secured.

The series of trials initiated by the Bureau in 1946 were designed to determine (a) the validity of the preliminary results under various weather and soil conditions ; (b) the effect of varying times and methods of application of the dust ;

(c) the minimum effective dose ; and (d) phytotoxicity to the cane crop and to legume crops in the rotation.

Since only a small quantity of "Gammexane" dust was available for experimental purposes in 1946, trials were largely of an exploratory nature. These trials contained a series of single treatment plots, each three rows wide by one chain long, interspersed with suitable checks. They were placed on a number of different soil types and in districts with different weather conditions.

Some of the exploratory trials were deliberately set out in areas that were unlikely to become grub infested, so that any toxic action which "Gammexane" might have on the cane plant could be readily evaluated.

In other cases, where grub infestation was a distinct possibility, they were set out as early as August in order that the young cane would be growing in proximity to the insecticide for at least six months before any serious grub infestation could develop ; it was considered that any phytotoxic effect which the insecticide might produce should begin to be apparent before then. Thereafter, the treatments were to be used as an indication of the dosage requirements for grub control. The rates of application used in these exploratory trials were 12½, 25, 50, 75, 100, 125, 150, 200 and 400 lb. of 10% "Gammexane" dust (1.3% gamma isomer) per acre. During 1946 and 1947 a limited number of Latin square and randomised block trials, with plots of 1/20th acre, were put down in an attempt to secure more reliable statistical data. Rates of application in these latter trials varied between 50 and 400 lb. of 10% dust per acre.

In all, 64 trials were established in 1946 and 1947, 10 being replicated plot trials and the remainder exploratory. Their distribution in the various cane-growing districts liable to grub infestation was as follows :—Mossman, 7 ; Cairns-Gordonvale, 30 ; Babinda, 6 ; Innisfail-Tully, 16 ; Burdekin, 5.

Grub infestation following the 1946 and 1947 beetle flights was generally light, and many plots failed to yield useful information because of lack of infestation or very light infestation. A few, however, became moderately infested and results from them formed the basis of further experimental work. During 1948 and 1949 there was a substantial upsurge in pest populations, and a summary of the information secured in those years is given in the following sections.

Phytotoxicity

In a series of tests carried out at the Northern Sugar Experiment Station, Gordonvale (Buzacott, 1948), "Gammexane" intimately mixed with soil caused no observable effect on the development of the shoot buds on cane setts germinating therein, but there was an inhibition of both primary and secondary root development. On the other hand, when the insecticide was applied in the field to the soil surface along the rows of germinated cane and worked in with the usual cultivating implements, no effect on growth was apparent, even when the crude benzene hexachloride was used at the rate of 60 lb. per acre. Laboratory trials with each of the pure alpha, beta, gamma and delta isomers indicated that the gamma isomer was the least phytotoxic. McDougall (1948) in work on control of the wireworm

Lacon variabilis also noted stunting of primary roots developing from the cane sett under some conditions where they contacted the insecticide. For that reason, in his earlier recommendations for the control of these pests, he advocated that the "Gammexane"-fertilizer mixture (20 lb. of 10% "Gammexane" dust + 3 cwt. fertilizer per acre) should be applied in the drill at planting time in such a manner that it would fall just above but not in direct contact with the setts. In later experiments (McDougall, 1949), he demonstrated that even if the "Gammexane"-fertilizer mixture came in partial contact with the setts there was no significant depressing effect on ultimate yields.

Hughes (1949) reported that he had cultured soil bacteria and fungi on nutrient agar in the presence of "Gammexane" and growth of the soil organisms had not been inhibited unless in actual contact with the insecticide. However, he concluded that at normal dosage rates "Gammexane" would have practically no effect on the soil micro-flora.

In the field trials, satisfactory germination and growth were secured where "Gammexane" was applied at the rate of 150 lb. of 10% dust per acre as a broadcast dressing, and at 100 lb. per acre in the drills prior to planting.

In one field experiment in which "Gammexane" was broadcast at the rate of 1,000 lb. of 10% dust per acre and later worked into the soil, there was a slight stunting effect in the early stages of the cane's growth, but later this effect became barely discernible. Plants of Poona pea (*Vigna unguiculata*), which is frequently grown as a green manure crop following cane, showed no adverse effects when grown under high concentrations of this insecticide.

In ratoon cane which was treated at rates of up to 600 lb. of 10% dust per acre by opening up furrows on each side of the cane row and applying the dust in them, there was an excellent development of roots, and the stools became so well anchored that they were difficult to remove when an examination of the root system was subsequently made. Not even the heaviest application caused damage to the resulting crop in this case.

There were many field trials involving applications as high as 400 lb. of 10% dust per acre, either as band dressings to the drills or as broadcast dressings disced in or ploughed under, and in none of these was any phytotoxic effect noticeable. On the other hand, even in the absence of grubs in both treated and control plots, some of those at the higher treatment levels often showed slightly better growth and a darker green foliage. This phenomenon was not due to some fertilizer value possessed by the insecticide, for in a replicated trial in the Innisfail area (Table 2),

Table 2

Summary of Yields of Cane in Toxicity Tests in the Absence of Grub Infestation.

Treatments	"Gammexane" 10% dust, per acre			CS_2 app 200 lb per ac.	Check
	100 lb.	150 lb.	200 lb.		
Cane, tons per acre	26.66	24.82	25.74	25.13	24.65
Percentage mean yield ...	105.0	97.7	101.3	99.0	97.1

which failed to become grub infested, the various treatments had no effect on yields. The farm selected for this trial normally showed a response to a complete fertilizer mixture.

The required difference for significance at the 5% level was 3.00 tons, so it is obvious that the "Gammexane" dressings produced neither a depressing nor a beneficial effect on crop growth.

Many of the treatment levels cited in the various experiments were considerably in excess of the minimum required for effective grub control under the most exacting conditions and, since no phytotoxic effects were noticed except at the highest level tested (and then they were only slight), it seems safe to conclude that no adverse effects are likely to follow normal applications of this insecticide to cane lands for grub control.

Method of Application

Band versus Drill.

The earliest field trial with "Gammexane" against cane grubs was conducted by applying the insecticidal dust to the plant cane as a band some 15-18 inches wide along the drill after the cane had germinated and become well established. By the time the field had finally been worked level with cultivating implements the insecticide was well incorporated in the soil around the base of the cane stools. Using a dosage rate of 100 lb. of 10% dust per acre, a mortality of 85% was recorded while the grubs were still in the first larval stage, and practically 100% kill was secured before they had reached the late second stage. From this it will be evident that, as grub attack developed and the young grubs moved in laterally towards the cane rows, they contacted the "Gammexane"-contaminated soil near the base of the cane stools and quickly succumbed. Thus complete control was effected before it was possible for the grubs to inflict any appreciable damage on the cane stools.

This band method of application is the one most commonly used at the present time, but a slight modification is necessary when treating ratoon crops. In this case it is customary to open up a furrow on each side of the cane rows with either a plough or some other ratooning implement, the dust being distributed in the furrows so formed. These furrows are then filled in either with grubbers or by "bursting" the centres of the interspaces.

Though the band method of application was found to be efficacious, it was thought desirable to test various broadcast methods, particularly since Buzacott, in an unpublished report, had stated that a concentration of one part per million of the gamma isomer in soil was sufficient to cause death of half the beetles within three days. Consequently, the idea of blanketing whole fields with "Gammexane" in an attempt to intercept beetles as they emerged, or as they returned to the fields to oviposit, was developed. Moreover, in the case of beetles that might evade the poison and succeed in laying, there was the added possibility that the small grubs would die before they could develop any degree of resistance to the insecticide. Accordingly a number of broadcast dressings were made in which the insecticide was spread over the entire drills and interspaces after the cane had germinated.

Cultivating implements later mixed the insecticide with the surface soil. In other instances, after being broadcast, the " Gammexane " dust was ploughed under or disced in before the fields were planted.

There was nothing to show that one method of broadcasting was superior to another, and though all exercised some measure of control the results were inferior to those produced by the same amount of insecticide applied to the cane rows as a band dressing. In one trial a 100 lb. broadcast treatment was only as effective as a 50 lb. band treatment. In another trial a 300 lb. broadcast treatment gave the same measure of control as a 100 lb. band treatment. In still another, which became lightly infested, a broadcast dressing of 100 lb. per acre permitted general light damage over the entire plot, whereas a band dressing of 100 lb. per acre, properly applied, has not been known to fail in affording a crop of plant cane complete protection against even the heaviest infestations. Hence, broadcast dressings are obviously uneconomical to use for this purpose, since they require some two or three times the quantity of insecticide to effect the same degree of grub control as that achieved with band dressings.

Machinery.

" Gammexane " applications were at first made either by hand or from a tin having a perforated bottom and attached to a handle about four feet long and an inch in diameter. In the latter case the tin was held over the cane rows as the operator walked along, and the insecticide was distributed evenly by tapping the handle. Upwards of five acres per man per day were treated in this manner.

Farmers were encouraged to adapt existing machines to their requirements, and Wilson (1948) described a number of fertilizer distributors which, with minor alterations, were found satisfactory for applying " Gammexane " as a band dressing.

Some of the alterations suggested involved an extension of the chutes so that the dust would be delivered right on the surface of the cane drill with a minimum of disturbance by wind. The tynes were so adjusted that they served to incorporate the " Gammexane " in the soil and at the same time destroyed any small weeds in the rows. Thus routine cultivation work and the application of the insecticide were carried out simultaneously. In addition, special provision was made to prevent the implements from moving sideways on hillsides and distributing the " Gammexane " outside the cane rows.

Humphry (1948) also described and illustrated a method whereby a standard fertilizer box was attached to the front cultivator bar of a high clearance tractor and distribution of the " Gammexane " was effected by a sprocket-and-chain driven mechanism operated from the back axle. This unit was capable of treating 20 acres per day.

Despite the improvisations made, it was soon found that the number of machines in some mill areas was too small to cope with all the fields that needed treating, and consequently other machines were developed expressly for the application of " Gammexane." For the most part they resembled in operation a narrow lime spreader, and about 10 acres per day could be treated.

Some of the earlier machines tended to apply the dust thinly over too wide an area, and in some extreme cases virtually the whole of the interspace was covered while a large portion of the drill was left untreated. Growers then had to rely on their subsequent cultivation operations to transfer the insecticide into the cane rows. This was seldom possible. Most of the few reported failures in grub control have been traced to application of the insecticide in the interspace with no subsequent movement of the treated soil into the cane rows.

These faults were subsequently corrected, and later modifications to these machines, which involved blocking up some of the outer delivery holes and narrowing the chutes, resulted in a marked improvement in the placement of the dust, while some of the newer machines aimed at applying the dust in a more concentrated band in the drill.

Time of Application

In the initial trial with "Gammexane" the forecast regarding infestation was accurate, and heavy oviposition occurred in the trial area some five to six weeks after the dust had been applied to the cane rows. Successful control of the resulting grubs was subsequently obtained. Some growers, however, are reluctant to institute control measures until the pest is actually established in the fields. Hence, several trials were set out to determine the latest period at which "Gammexane" could be applied for successful control. Treatments involving various dosage levels were applied as follows :—

(a) One to two months before beetle flight.

(b) During beetle flight.

(c) One month after beetle flight.

(d) Two months after beetle flight.

(e) Three months after beetle flight.

Results showed that satisfactory control was secured if applications were made at any time prior to or during beetle flight. There was some control when the dust was applied a month after beetle flight, but at normal treatment levels the damage subsequently inflicted by grubs was sufficiently severe to render it risky. Proportionately lower control was effected by later applications, and in an application made two months after beetle flight there was damage in all treatments up to and including the 200 lb. per acre band dressing. When the treatments were made three months after beetle flight, damage was severe at the 200 lb. rate and was also apparent at the 400 lb. rate. Since grub surveys do not usually give a reliable picture of infestation before two months after beetle flight, "Gammexane" applications made immediately afterwards on the basis of this information would at best yield poor control at the higher treatment levels, while later applications would prove virtually useless. In addition, there are various practical considerations which militate against success with these late applications. In the first place, a factor to be reckoned with is the height of the cane at the time when these late dressings would have to be applied. Not only would a considerable number of stalks be snapped off as the distributing implements passed either over the rows or along the interspaces, but the breadth of the stool would also render difficult the application of the dust in or near the cane rows and its admixture with the soil near the stools. In addition, heavy monsoonal downpours are normal at that time of the year and would be expected to prevent the working of implements on the land. If recourse were made to hand application, the difficulty of incorporating the dust in a thoroughly saturated soil would still present a problem.

From a consideration of the foregoing, it is evident that for maximum benefit "Gammexane" must be applied before or during beetle flight, but considerable latitude is allowable and the question of arriving at the optimum time for application becomes a matter of determining the most suitable time to fit this control work in with ordinary routine cultivation. Normally, the cane rows are kept open until the cane is adequately stooled and then filled in gradually until the land is restored to a level state by the time the cane is "out of hand." Therefore, if "Gammexane" is applied just before the soil is worked back, it will remain in the rows and become intimately mixed by subsequent tillage operations, thus fulfilling the basic requirement regarding placement. Hence, the time to apply "Gammexane" depends primarily on the stage of development of the crop and this in turn depends on the time of planting and the conditions for subsequent growth. However, in most instances plant crops will be ready to receive their treatment between August and November ; ratoon crops obviously would require treatment at the time of ratooning.

Rates of Application

Since a dressing of 100 lb. of "Gammexane" per acre had proved satisfactory in the initial test, in subsequent trials the rate of application ranged from 100 lb. down to 12½ lb. per acre, though heavier dressings were tested on other soil types.

An application at the rate of 25 lb. per acre gave inadequate control for practical purposes, but the 50 lb. treatment appeared satisfactory in dealing with light infestations on heavy soil. The latter rate, however, was unable to cope with light infestations on friable soils or with moderate infestations on medium to heavy soils, where in one instance up to four grubs per stool were involved. In these plots there were unmistakable signs of grub attack, such as yellowing of the foliage, root pruning, and some destruction of the basal portion of the stool. Since the precautionary measure of applying "Gammexane" for grub control would imply an expectation of at least light infestations on friable soils or moderate infestations on heavier soils, the 50 lb. dressing is considered too low for the first application to either plant or ratoon cane.

A dressing of 75 lb. per acre proved adequate in dealing with light to moderate infestations in either plant or ratoon cane, but it proved insufficient to prevent damage showing up in some plant crops in which heavy infestations (from five to 18, with an average of approximately 12, grubs per stool), were involved. There was also evidence to show that it was less satisfactory than the 100 lb. treatment on a block of ratoon cane growing on friable red soil in the South Johnstone area. In general, it appears that 75 lb. per acre is the lowest amount that should be applied for a single crop treatment of plant or ratoon cane (*see* Fig. 3 for an illustration of the value of an 84 lb. dressing), and even then it should be restricted to the heavier soils. When assessing the value of various treatments for crop protection,

Figure 3.
A crop of plant Trojan cane showing the effect of an application of 84 lb. 10% "Gammexane" dust per acre. Cane on right treated; cane on left untreated.

Figure 4.
A crop of ratoon cane showing the effect of an application of 84 lb. 10% "Gammexane" dust per acre to the plant crop. Cane on right treated; cane on left untreated.

Table 3

RESULTS OF BADILA PLANT CROPS HARVESTED FROM TWO 12 × 4 RANDOMISED " GAMMEXANE " 3-YEAR PERSISTENCE TRIALS.

Treatment rates in lb. per acre	No. of Plots	FARM D.—Clayey Schist Soil. " Gammexane " applied 19/10/48. Plant crop harvested 17/8/49. Average grub population per untreated stool=6.4		FARM P.—Grey Schist Soil. " Gammexane " applied 27/10/48. Plant crop harvested 5/7/49. Average grub population per untreated stool=12.	
		Mean Yields in tons per acre	Remarks	Mean Yields in tons per acre	Remarks
0	4	22.74	Cane showed obvious signs of extensive grub damage.	22.42	Cane lodged and uprooted in all plots. Considerable grub damage.
200 lb. carbon bisulphide.	4	23.81	Cane showed evidence of earlier grub attack. Fumigated 28/4/49. Grub mortality 85%.	24.34	Cane lodged and damaged. Fumigated 9/5/49. Grub mortality 64%.
75 lb. 10% 'Gammexane "	16	29.54	No visible grub damage.	31.66	Slight grub damage apparent by wilting and yellowing of foliage.
100 lb. 10% "Gammexane"	12	30.3	No visible grub damage.	32.11	No visible grub damage.
125 lb. 10% "Gammexane"	8	30.14	No visible grub damage.	30.08	No visible grub damage.
150 lb. 10% "Gammexane"	4	28.45	No visible grub damage.	30.83	No visible grub damage.

In the above trials the 75, 100 and 125 lb. treatments with 10% " Gammexane " dust on Farms D and P and the 150 lb. treatment on Farm P all exceed the carbon bisulphide and nil treatments at the 1% level of significance, while the 150 lb. treatment on Farm D exceeds the carbon bisulphide and nil treatments at the 5% level of significance. Other differences are not significant.

yield differences should not always be accepted as the final criterion. Grub damaged blocks are usually harvested soon after the commencement of crushing operations and before any considerable crop deterioration has occurred, hence damage which is not always apparent in yield may often be reflected in decreased vigour in the following ratoon crop (*see* Fig. 4).

A 100 lb. dressing, properly applied, controlled the heaviest infestations in plant and ratoon crops under all conditions even when populations approached 20 per stool. This, then, has been fixed as the standard treatment where a single crop needs protection against heavy infestation.

Table 3 shows yields of the plant crops from the randomised "Gammexane"-persistence trials which were established in 1948. As originally planned, these trials included various combinations of treatments divided between the young plant cane and first ratoons for comparison with equivalent amounts applied as single dressings to the plant cane. So far, only the plant crops have been harvested; however, the degree of control achieved with the 75 lb. and 100 lb. treatments is of interest, and the results substantially confirm the conclusions outlined above.

On farm D the 75 lb. rate of treatment sufficed to control the moderate infestation on the heavier soil there, since there was no evidence of grub damage developing in those plots. On the other hand, farm P suffered a very heavy infestation of grubs and, although in this instance the 75 lb. treatment showed no loss in tonnage when compared with the higher rates of treatment, there was a definite wilting and yellowing of the foliage through grub attack. This indicated that control had not been complete and the vigour of the subsequent ratoons could have been adversely affected. Plots treated at rates of 100 lb. per acre and over showed no signs of grub damage.

The carbon bisulphide treatments, because of unfavourable weather conditions, had to be delayed until April 28 and May 9, 1949, respectively, and even then only 64 per cent. mortality was obtained on Farm P. In those circumstances it was inevitable that considerable grub damage would develop, a typical happening in previous years during any normal fumigation campaign. The carbon bisulphide plots averaged one to two tons per acre more than the untreated plots, but the differences are not significant, and the chief gain in these cases would have been in saving the stools for the ratoon crops. On the other hand, the results demonstrated very forcibly the superiority of the "Gammexane" treatments, which gave a highly significant increase of seven to eight tons per acre over the check plots.

Re-treatment of Ratoons

In the original field experiment "Gammexane" remained toxic for five or six months, and it was reasonable to expect that it might retain some of its toxicity into the following ratoon crop. Accordingly, in further trials, after the plant crops had been harvested and the blocks ratooned, a "booster" treatment was applied as side dressings to furrows made alongside the rows of all plots except those which had received over 200 lb. per acre, in an attempt to restore an effective level of toxicity. The rate for re-treatment was fixed at 50 lb. per acre, as any quantity substantially below this figure would have involved difficulties in application.

Results from these re-treatments showed that, where a light to moderate infestation was involved in the friable red volcanic soils at South Johnstone, there was a definite response to a " booster " dressing of 50 lb. per acre in the case of original treatments of 50 lb. and 75 lb. per acre, but original treatments of 100 lb. and over showed no benefit from this re-treatment. In a heavy infestation on medium soil in the Mulgrave area, a treatment of 40 lb. per acre to the first ratoons gave a substantial improvement where a grower had applied to the plant crop a dressing at the rate of 92 lb. per acre (*see* Fig. 5).

Figure 5.

A crop of ratoon cane showing the effect of a " booster " application of "Gammexane" to the ratoon crop. The whole block was treated in October, 1947, at the rate of 92 lb. 10% "Gammexane" dust per acre. The cane on the left was given a " booster " treatment at the rate of 40 lb. per acre in November, 1948, and was undamaged. The cane on the right received no additional treatment and showed moderate grub damage. The photograph was taken in July, 1949.

This method may be quite important in the Burdekin area. There, during ratooning operations, it is customary to slice away a considerable portion on each side of the stool, and this is turned over into the interspace. By adopting this method of ratooning a considerable proportion of the original " Gammexane " dressing may be carried over with the soil adhering to the sliced portions of the stool, and this is never replaced in exactly the same relative position. Consequently, the continuity of the " Gammexane " barrier may be destroyed, but it could be restored by re-treatment as outlined above.

Residual Toxicity Without Re-treatment

In the original approach to the problem of grub control with " Gammexane," the emphasis was mainly on the minimum dressing necessary for effective protection of one crop, for it was scarcely conceived at that time that this material, when placed in the soil, would remain toxic over a period of some years. The early experiments were accordingly designed to give information on minimum dressings. However, in view of the fact that the insecticide remained toxic for a number of months it was decided that some plots or portions of plots should not be re-treated, in order to ascertain just how long different concentrations would remain effective.

Table 4

DATA AND OBSERVATIONS FROM EXPLORATORY TRIALS IN THE MULGRAVE AREA, SHOWING PERSISTENCE OF TOXIC EFFECT OF " GAMMEXANE " INTO THE RATOONS FOLLOWING SINGLE DRESSINGS TO PLANT CROPS OF BADILA.

Treatment rates in lb. 10% " Gammexane " dust per acre applied as band dressings along cane rows	Results in 1st ratoon crop on Farm A. Treated 21/11/46. Very heavy grub infestation in 1948			Remarks on second ratoon crop on Farm B. Treated Nov. 28, 1946. Very heavy grub infestation in 1949. Harvested June 14, 1949, but no records of plot weights secured†
	Mean Grub population per stool at May 18, 1948	Yields in tons per acre, June, 1948	Remarks*	
Nil (av. 4 plots)	11.0	21.4	Cane tops dying and ready to break off.	Cane severely damaged and pinched off in all plots, uprooted and foliage dying.
12½	12.0	20.6	Almost no grub control.	No apparent control.
25	8.0	20.5	Very little grub control.	No apparent control.
50	4.5	27.3	Substantial grub damage but better than 25 lb. treatment.	Slightly better than check plots but considerably damaged.
75	1.5	27.6	Noticeable grub control.	Slightly better than check plots but considerably damaged.
100	.5	26.7	Very slight grub damage.	Foliage losing green colour and some damage noticeable. Considerable loss in growth compared with 150 and 200 lb. treatments.
125	.5	29.0	No obvious signs of grub damage.	Foliage losing green colour and some damage noticeable. Cane growth satisfactory but less cane than 150 lb. treatment.
150	1.0	27.3	No obvious signs of grub damage.	Foliage green ; cane growth good ; no apparent grub damage.
200	.5	32.1	No obvious signs of grub damage.	ditto.

* When sampled for analyses in June, 1948, some sticks in the samples from damaged plots on Farm A had pinkish-red areas (red rot) developing in the internodes.

† When diggings were made on 1/6/49, it was evident from the number of bandicoot holes in different plots that many grubs had been destroyed by these animals. However, bandicoots had not apparently interfered with the 150 lb. and 200 lb. plots, which showed an average of 4.25 and 4.5 grubs respectively per stool. The check adjacent to the 150 lb. treatment showed an average of 12.25 grubs per stool even after having been raided by bandicoots.

Figure 6.
A second ratoon crop of Badila cane showing the effect of the residual toxicity of "Gammexane" to grubs. The cane on the right was treated in the plant crop in November, 1946, at the rate of 200 lb. 10% "Gammexane" dust per acre. The cane on the left was untreated. The photograph was taken in July, 1949. (See last column of Table 4 for further information.)

Figure 7.
A second ratoon crop of Cato cane showing the effect of the residual toxicity of "Gammexane" to grubs. The cane on the left was treated in the plant crop in November, 1946, at the rate of 150 lb. 10% "Gammexane" dust per acre. The cane on the right was untreated. The photograph was taken in July, 1949. (See Table 5 for further information.)

Table 5

SUMMARY OF YIELDS AND OBSERVATIONS IN A LATIN SQUARE TRIAL ON FARM C, MULGRAVE AREA, SHOWING RESIDUAL TOXICITY OF "GAMMEXANE" IN RATOON CROPS OF CATO AFTER SINGLE DRESSINGS TO THE PLANT CANE.

PLANTED MAY, 1946, ON BROWN SCHIST SOIL. TREATMENTS APPLIED 12/11/46.

Date of Harvesting	Yield in tons per acre at treatment rates indicated in lb. of 10% "Gammexane" dust per acre				Remarks
	nil	100 lb.	150 lb.	200 lb.	
12/11/47	27.04	28.09	28.83	28.82	Light grub infestation, approx. 1 per stool in controls; 200 and 150 lb. treatments exceed check at the 1% level.
16/8/48	27.51	34.13	35.78	34.90	Heavy infestation. Considerable damage visible in controls and slight damage in 100 lb. treatment. None in 200 and 150 lb. treatments; 200, 150 and 100 lb. treatments exceed check at the 1% level.
29/6/49	10.18 (8 2)*	17.71 (4.9)	20.1 (3.4)	20.71 (2.6)	Very heavy infestation. Heavy damage in control plots and considerable damage visible in 100 lb. treatments. No damage visible in 200 and 150 lb. treatments; 200 lb. and 150 lb. treatments exceed 100 lb. treatment and check at the 1% level; 100 lb. treatment exceeds check at the 1% level.
Totals for 3 crops ...	64.73	79.93	84.71	84.43	

* Early diggings in 1949 showed high grub populations averaging approximately 15 per stool, but when subsequently dug on 25/5/49 average grubs remaining per stool in different treatments were then as shown in brackets.

In 1948 a series of first ratoon plots which had been treated as plant cane in November, 1946 became heavily infested. So badly was the crop damaged outside the boundaries of the plots that the grower decided to plough the block out. Hence, in this instance, though data were secured from the first ratoon, no information was available regarding possible carry-over effects into the second ratoon crop. However, another block that was treated in 1946, and which virtually escaped infestation in 1947 and 1948, became heavily infested in 1949—i.e., in the second ratoon crop. Results of these two exploratory trials and a Latin square trial were so striking that full details are presented in Tables 4 and 5. The effect on two of the farms is illustrated in Figures 6 and 7.

Ratooning operations in the above experiments were carried out with grubbers or similar implements, the use of which involved no great movement of the soil away from the cane rows; thus the "Gammexane" remained practically *in situ* throughout the entire period occupied by the three crops. The one-treatment schedule, then, should be applied only under these conditions.

When considering the tonnage losses in the above experiments, it should be noted that any differences between treatments represent minimum differences, for had harvesting been delayed the effects would have become progressively worse as the season advanced. It has previously been pointed out that yield comparisons do not always adequately reflect the value of certain treatments unless they are interpreted with other data. It is also misleading to judge the efficacy of a treatment solely on the basis of the number of live grubs revealed by diggings, since some grubs might not have contacted the band of insecticide whilst others might be immobilized and unable to injure the plant. For instance, in the second ratoon crop on Farm C, the May diggings revealed that, though a gradual and substantial reduction in grubs had occurred, there still remained a small but appreciable population which under normal circumstances would have been capable of inflicting visible damage. However, insofar as the 150 and 200 lb. treatments were concerned, it is considered that many of these grubs were immobilized, since no damage could be seen in these plots. The limited diggings carried out on Farm B appear to confirm these general conclusions. It seems, therefore, that the final decision regarding the efficacy or otherwise of a particular treatment must depend on whether or not plots so treated remain free from noticeable grub damage ; yield data and grub populations provide valuable supporting evidence.

Referring to results in the first ratoons during the 1948 season on Farms A and C (Tables 4 and 5), it can be seen that there was slight damage noticeable in both at the 100 lb. level of treatment, while in the second ratoon crop on Farm B in 1949 the 100 lb. and 125 lb. treatments proved inadequate. In the same year the 100 lb. treatment on Farm C, as well as showing substantial damage, also disclosed a small but significant tonnage loss when compared with the 150 lb. treatment. While some of this loss may have been due to the direct effect of grub attack during 1949, a portion at least of this was due to a reduction in vigour of the ratoons following some damage in these plots during 1948. Furthermore, a substantial proportion of the 7½ tons difference shown in 1949 between the control and the 100 lb. treatment was due to a difference in ratooning potential following the severe damage sustained by these control plots in 1948.

The 125 lb. treatment on Farm A gave satisfactory protection over a period of two crops, while the 150 lb. treatment on Farms B and C gave complete protection throughout the three crops. No increased benefit was derived from dressings in excess of 150 lb.

Taken over the three crops, the 150 lb. treatment on Farm C showed a highly significant increase over the check plots each year, and in the aggregate this increment amounted to almost 20 tons. This figure is a conservative one for infestations of this severity, since the heaviest attack occurred at the end rather than at the commencement of the cropping cycle ; moreover, when the crops were badly damaged they were harvested during the early part of the crushing season. Nevertheless, the tonnage gain in the 150 lb. treatments represents a net return of approximately £45 per acre against an outlay not exceeding £7 10s. for material and costs of application.

It will be evident from the severity of the infestations on Farms A and C in 1948 and on Farm B in 1949 that, if weather conditions are favourable, heavy grub populations can build up quite rapidly in places where only light infestations were apparent in the previous year. Consequently, although no signs of grubs may be evident at planting time, growers in areas liable to damage cannot risk heavy infestations at some subsequent period within the crop cycle. Hence the treatment rate should be adequate to provide sufficient residual toxicity to cope with even the heaviest of infestations throughout the growth of the second ratoon crop. The 150 lb. plant crop dressing fulfils this requirement.

Normally, most canegrowers in North Queensland follow a four-year rotation, and on the basis of the above results it is now possible to recommend a treatment rate of 150 lb. of 10% " Gammexane " dust per acre applied to the young plant crop as a band dressing along the rows. Similarly, in those districts where it is usual to grow only a plant and first ratoon crop, a single dressing of 125 lb. applied to the plant crop is recommended. These single treatments will ensure complete protection against grubs of the greyback bettle over the entire crop cycle, and they are recommended in preference to the 100 lb. treatment with subsequent " booster " dressings as required. The latter, of course, entail additional labour and expense.

Form of Dust

The first " Gammexane " dusts supplied were manufactured on a pyrophyllite base but, because of the tendency of this dust to " fly " and because of the scarcity of pyrophyllite at that time, a change-over to a rock phosphate-pyrophyllite base was soon made after experiments had shown that rock phosphate alone as a base could not be processed satisfactorily.

Present-day dusts therefore are mainly mixtures of benzene hexachloride, pyrophyllite and rock phosphate in varying proportions. Gypsum and kaolin have been tried as diluents, but up to the present they have not been used extensively under field conditions, though some companies are now offering benzene hexachloride dusts processed on one or other of these bases.

Throughout all of the experimental work reported previously, a 10% " Gammexane "-pyrophyllite dust was used in preference to a " Gammexane "-rock phosphate dust solely in order to eliminate any differences due to the fertilizer value of the rock phosphate, since this would have complicated the interpretation of results. From the agricultural viewpoint, however, this fertilizer value of the diluent is an advantage, and on that account preference is being shown for benzene hexachloride dusts containing a high percentage of rock phosphate rather than for those manufactured on some otherwise worthless diluent.

In the early experiments the 10% dust proved a suitable form in which to distribute evenly the relatively light dressings of " Gammexane " that were being tested, and growers subsequently used the same material in the larger scale control operations on their farms. When first quoted, the price of the 20% dust at 1s. 8d. per lb. was twice that of the 10% material, and with control measures then being carried out on a year-to-year basis there was little incentive at that time to change over to the 20% product, since its use would have involved difficulties in application and treatment costs would not have been lowered. However, the position regarding the use of these two preparations altered materially in 1949 when, in the first place, a larger single dressing was recommended for control on a three-crop basis and, in the second place, the 20% product became available at 1s. 2d. per lb. in comparison with the 10% material at 10d. per lb.

The 20% dust had already been used successfully for grub control, and in view of this substantial reduction in price it became obvious that treatment costs would be appreciably lowered by applying the equivalent dressing of 20% "Gammexane." At a treatment rate of 75 lb. of 20% dust per acre this represented an outlay not exceeding £4/12/- per acre over a period of three crops, and as a result this product is now supplanting the 10% dust in cane grub control except where small supplementary dressings are required after ratooning.

PRESENT COMMERCIAL APPLICATION

In 1945 and 1946 the small amount of "Gammexane" available was fully utilised in investigational work, and it was not until 1947 that it first became available on a commercial basis. By that time some striking results from a number of experimental trials had become known, and because of its ease of application, efficacy and cheapness, it was quickly adopted by Queensland canegrowers in marked preference to other methods of grub control. Although 120 tons of 10% dust were supplied in 1947, this quantity did not meet requirements. Appreciable grub damage in the following years so increased the demand that it was not until the end of 1949 that the industry's needs were fully satisfied. In that season approximately 900 tons of benzene hexachloride dusts were delivered to growers for the treatment of an estimated 20,000 acres.

REFERENCES

BUZACOTT, J. H. 1946. Unpublished report.

————. 1948. The use of benzene hexachloride in North Queensland canefields. J. Aust. Inst. Agric. Sci. 14 : 24-7.

HUGHES, C. G. 1949. Reported discussion in Minutes and Proceedings of the Eleventh Conference of Cane Pest and Disease Control Boards, Mackay, Queensland.

HUMPHRY, E. V. 1948. A fertilizer and "Gammexane" distributor. Cane Growers' Quart. Bull. 11 : 177-9.

ILLINGWORTH, J. F., AND DODD, ALAN P. 1921. Australian sugar-cane beetles and their allies. Qld. Bur. Sugar Exp. Stas. Div. Entom. Bull. 16.

JARVIS, E. 1927. Notes on insects damaging sugar cane in Queensland. Qld. Bur. Sugar Exp. Stas. Div. Entom. Bull. 3 (2nd ed.).

KNUST, H. G. 1934. Control of cane grubs in North Queensland by fumigation. Proc. Qld. Soc. Sugar Cane Tech. Fifth Annual Conference, Cairns, Queensland : 203-5.

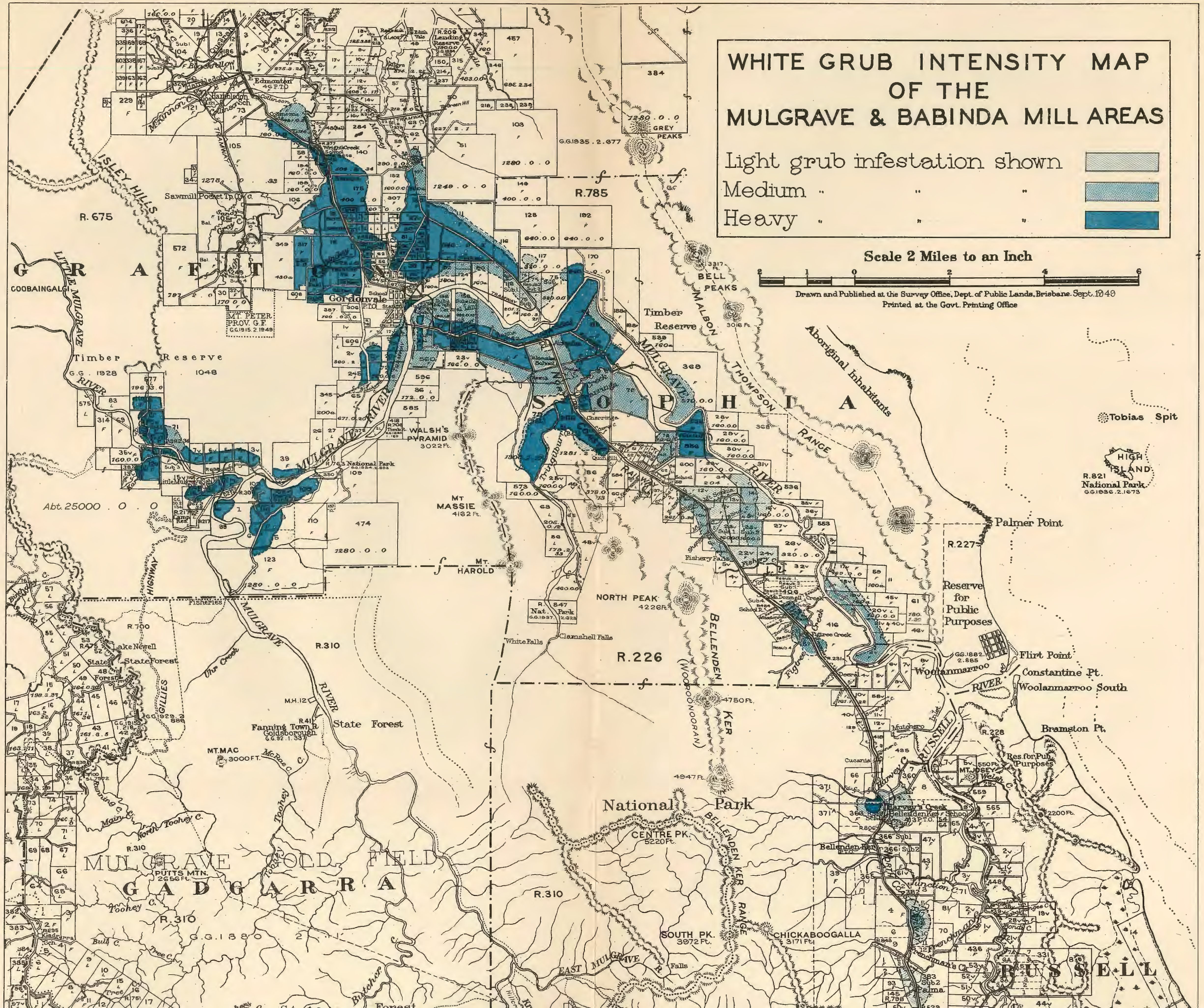
McDOUGALL, W. A. 1948. Wireworm control. Report of Minutes and Proceedings of the Tenth Conference of Cane Pest and Disease Control Boards, Cairns, Queensland.

————. 1949. Wireworm control. Report of Minutes and Proceedings of the Eleventh Conference of Cane Pest and Disease Control Boards, Mackay, Queensland.

MUNGOMERY, R. W. 1946. "Gammexane"—A promising chemical for cane grub control. Cane Growers' Quart. Bull. 10 : 6-7.

————. 1948. The use of benzene hexachloride in controlling "white grubs" in Queensland cane fields. Proc. Qld. Soc. Sugar Cane Tech. Fifteenth Conference, Maryborough, Queensland : 35-42.

WILSON, G. 1948. Field applications of "Gammexane" dust in the South Johnstone Mill Area. Report of Minutes and Proceedings of the Tenth Conference of Cane Pest and Disease Control Boards, Cairns, Queensland.



WHITE GRUB INTENSITY MAP
OF THE
MULGRAVE & BABINDA MILL AREAS
Light grub infestation shown
Medium " " "
Heavy " " "
Scale 2 Miles to an Inch
Drawn and Published at the Survey Office, Dept. of Public Lands, Brisbane. Sept. 1949
Printed at the Govt. Printing Office
GRAFTON
SOPHIA
GADGARRA
RUSSELL
MULGRAVE GOLD FIELD
Gordonvale
ISLEY HILLS
LITTLE MULGRAVE RIVER
MULGRAVE RIVER
Timber Reserve 1048
WALSH'S PYRAMID 3022Ft.
MT MASSIE 4182Ft.
MT. HAROLD
NORTH PEAK 4226Ft.
CENTRE PK. 5220Ft.
SOUTH PK. 3872Ft.
CHICKABOOGALLA 3171Ft.
BELL PEAKS
GREY PEAKS
MALBON THOMPSON RANGE
BELLENDEN KER RANGE
National Park
State Forest
Aboriginal Inhabitants
Tobias Spit
HIGH ISLAND
R.821 National Park
Palmer Point
Flirt Point
Constantine Pt.
Woolanmarroo South
Bramston Pt.
Reserve for Public Purposes
MT.MAC 3000FT.
PUTTS MTN. 2656Ft.
R.675
R.785
R.226
R.310

NORTH PEAK
R.226
BELLENDEN KER
National Park
CENTRE PK. 5220 Ft.
SOUTH PK. 3872 Ft.
CHICKABOOGALLA 3171 Ft.
MULGRAVE RIVER
R.310
State Forest
Fanning Town R.
MT.MAC 3000 FT.
MULGRAVE GOLD FIELD
GADGARRA
PUTTS MTN.
State Forest
Caribou Falls
EAST MULGRAVE R.
Bartle Frere G.M. Leases
BELLENDEN KER
Babinda
BARTLE FRERE (North Peak) 5001 Ft.
BARTLE FRERE (South Peak) 5287 Ft.
RUSSELL
Flirt Point
Constantine Pt.
Woolanmarroo South
Woolanmarroo
Bramston Pt.
MT. JOSEY
for Public Purposes
GRAHAM RANGE
Wyvuri Swamp
MT. GRAHAM
BABINDA COAST ROAD
Miriwinni
Pawngilly
Eubenangee Swamp
Glen Allyn
Butchers Creek School
CONZELMANN BLUFF
BARTLE FRERE EXTENDED
RUSSELL GOLD FIELD
Camelia Falls
MT. FLETCHER 2700 Ft.
TWIN PINNACLES
CHALMYNIA MT. 1100 Ft.
RUSSELL RIVER
GLADYS
NARES