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Insecticidal control of white grubs (Coleoptera:Scarabaeidae) on the Atherton Tableland, with observations on crop losses

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Abstract

Eight chemical treatments were tested against large white grubs (*Lepidiota* spp.) in maize and peanuts on the Atherton Tableland, Queensland. Terbufos at 2 and 4 kg a.c./ha increased yield by up to 0.985 t/ha in maize and significantly decreased grub populations. In the same experiment EDB-treated areas had significantly fewer white grubs than the untreated plots. In peanuts, terbufos and phorate (both at 2 kg a.c./ha) reduced white grub populations 49 days after application but there were no differences in either crop yield or white grub populations at harvest. Chlorpyrifos was ineffective applied as either an emulsifiable concentrate or granules. The relationship between white grub numbers at harvest and peanut yield was linear, with one white grub per 3 m of row reducing nut in shell yield by 12 g. In a second trial in peanuts, where all chemicals were used at 3 kg a.c./kg, ethoprophos, fensulfothion, isofenphos, phorate and terbufos significantly reduced grub numbers compared to the untreated plots but aldicarb did not.

INTRODUCTION

The role of white grubs of the genus *Lepidiota* in pasture deterioration on the Atherton Tableland of north Queensland has been well documented (Atherton 1931, 1939; Smith 1936; Saunders 1958). Other species such as *Dasygnathus dejeani* Macleay (*D. australis* Boisduval of Atherton, 1931) also occur. Although primarily pasture pests, white grubs sporadically attack maize, peanuts and potatoes (Crosthwaite 1983 and present study). Despite the serious losses which may occur there is no information on either their control or the damage they cause.

White grubs are a perennial problem in sugar cane (Wilson 1969*a*; Hitchcock 1974) where traditionally they have been controlled by BHC (Buzzacott 1948; Mungomery 1948, 1949) and other organochlorines (Wilson 1969*b*). Recent studies on sugar cane have replaced these persistent chemicals with controlled release formulations of chlorpyrifos for long-term control (Hitchcock *et al.* 1984) and fensulfothion and ethoprophos for short-term control on *Lepidiota* spp. (B.E. Hitchcock, pers. comm. 1983). Insecticide trials against white grubs in sweet potato and maize were reported by Rolston and Barlow (1980) and McBride (1984) in the USA, by Ram and Yadava (1982) in peanuts in India and by Stewart (1984) in pasture in New Zealand.

Our aim was to evaluate insecticides for white grub control in field crops and, where possible, attempt an assessment of crop losses. Identification of the white grubs was difficult as they could not be bred to adults and circumstantial evidence is presented as to the identity of the larvae.

MATERIALS AND METHODS

Because of the sporadic nature of white grub attack trials could be set up only when opportunities arose. When signs of attack occurred early in a crop it was either ploughed out and replanted (with chemical treatments) or insecticides were applied to the existing planting.

Some *Lepidiota* spp. have a two-year life cycle and thus large one-year-old white grubs (third instar) may be present when the crop is planted. Trials on such large larvae (probably *L. laevis* Arrow) were undertaken in peanuts (1979) and maize (1981) on a farm east of Atherton. In 1982 second instar *Lepidiota* larvae caused lodging in maize on a farm between Tolga and Rocky Creek; between Atherton and Mareeba. The soil type on both farms was a krasnozem formed on basalt. A trial was also conducted on large *Lepidiota* larvae attacking peanuts in a deep fine sand (Mulligan fine sand, McDonald 1976) near Dimbulah in 1982.

Peanut trial, Atherton, 1979

The trial was laid down in a heavily infested crop of Virginia Bunch peanuts on 9 February 1979 when the crop was six weeks old. The design was a randomised block with four chemical treatments and a control (Table 1) replicated five times. To overcome patchiness of the infestation, plots were assigned to the different blocks according to the number of white grubs in a pretreatment count. Each plot consisted of 3 rows each 3.5 m long. Plots were separated laterally by one guard row and along rows by 1.5 m between adjacent plots. At the pretreatment count a trench 0.5 m long × 0.25 m × 0.25 m was dug from the end of each of the three datum rows in each plot. The white grubs were unearthed and counted.

Chemicals (Table 1) were applied by digging trenches 100 mm wide and 100 mm deep on either side of rows and as close as possible to the plants without damaging them. The required quantities of granules or emulsifiable concentrate were sprinkled or sprayed into the trenches which were then refilled with soil. The amount of chemical per metre was calculated on 11 000 m of row per hectare.

The first assessment was carried out 49 days after treatment. Trenches 1 m long × 0.25 m × 0.25 m were dug at the end of each of the datum rows. White grubs were counted and the immature peanuts removed and their dry weight determined. At final harvest (14 May 1979), a further metre of trench 0.28 m × 0.3 m was dug in each datum row leaving 0.5 m of undisturbed row on either side. The numbers of white grubs and plants were counted and the yield of sun dried nut in shell determined for each plot. Despite precautions in setting up the trial, there was large plot to plot variation within blocks in the number of white grubs at final assessment and in yield of nut in shell. An examination of the relationship between white grub density per plot and yield was therefore undertaken using regression analysis. For each of the five treatments the slopes and intercepts of the lines relating the two variables were compared. As there were no significant differences data were pooled and a common regression equation calculated.

Maize trial, Atherton, 1981

In mid January 1981 severe white grub damage appeared in 20 ha of maize which had been planted in mid December 1980. The maize was ploughed out and the trial was established in the area at replanting. Three chemical treatments (Tables 2 and 3) and a control were laid out in a randomised block with five replicates. Plots were eight rows wide and 250 m long. Because of the required minimum two week waiting period between ethylene dibromide (EDB) application and planting and the lateness in the season, the controls and terbufos treatments were planted first on 2 and 3 February 1981.

A four row planter equipped with a Gandy granule applicator was used to plant the maize (QK230) in 0.81 m rows with a 100 mm granule band beneath the soil near the seed. EDB 193 was applied at the rate of 15 L/ha mixed with 76 L/ha of water using a simple gravity fed applicator mounted behind a tractor. The applicator delivered the EDB into the soil behind six tynes and the soil was levelled after application. EDB was applied on 6 February 1981 and the maize was planted in the EDB treated plots on 20 February. Urea (46% N) was applied at 185 kg/ha to all plots in early March.

White grub density and plant size were determined 50 days after planting in the terbufos and untreated plots. Larval density was also determined in the EDB treated plots but no data on plant growth or on final yield was collected as the plants were 18 days younger than those in the rest of the trial. In the central four rows of each plot five 10 m lengths of row were chosen at random. The height of five plants selected randomly and the number of plants per 10 m of row were determined. A 2.5 m length of row was chosen at random from within the 10 m lengths and four plants complete with roots were removed. The plants were dried at 80°C for 3 days and weighed. A trench 2.5 m long, 0.3 m deep and 0.3 m wide was dug in each 10 m length and the number of white grubs counted. Cobs from three 10 m lengths of row were harvested from the centre of each plot in early July 1981 and the weight of grain at 14% moisture content recorded. The number of plants and the number of sterile plants in each 10 m length of row was also determined.

Peanut trial, Dimbulah, 1982

The crop of Virginia Bunch peanuts in which this trial was conducted was planted in December 1981 in land only recently prepared from Rhodes grass pasture. Within six weeks, damage by large white grubs was apparent. An experiment with six replicates and six chemical treatments (Table 4) was established in a randomised block design. The granules were sprinkled on the soil surface and covered with a light layer of sandy soil. Plots were three rows wide and 5 m long and the central metre of the central row was sampled 54 days after treatment. There was no assessment of final yield.

Observations in lodged maize, Tolga, 1982

In May 1982 widespread lodging occurred in six circular areas, each of 2 to 4 ha, in a 30 hectare field of mature QK657 maize. Within these areas all the plants were lodged. Examination of lodged plants showed numbers of second instar white grubs and damaged root systems. White grub numbers on lodged plants and adjacent unlodged plants were compared by sampling beneath 15 randomly selected plants in each area. A further 15 plants were examined for white grubs in an adjacent upright stand of well grown maize. To estimate yields, five lengths of row each five metres long were chosen at random in each of the three areas. All cobs were collected and shelled and the weight of grain at 14% moisture recorded. In addition 20 cobs were selected at random in one area of lodged plants and in one area of standing maize and the weights of the whole cobs recorded.

RESULTS

Peanut trial, Atherton, 1979

Granular formulations of phorate and terbufos significantly ($P<0.05$) reduced white grub populations compared with the untreated control 49 days after application. Both the granular formulation and the emulsifiable concentrate of chlorpyrifos were ineffective (Table 1). The mean dry weights of immature peanuts and the mean numbers of plants per metre at this time did not differ significantly (data not presented). Although the trend in white grub numbers at harvest followed that above, differences in populations were not significant at $P<0.05$ (Table 1). The ranges of larval density recorded indicates extreme variability in populations. There were also no significant differences in yields or in plant density. The ranges of yields per plot within treatments are also extreme, two fold variations being common (Table 1).

Table 1. Effect of insecticides on numbers of white grubs (*Lepidiota* sp. probably *laevis*), plant populations and peanut yield as nut in shell, Atherton, 1979

Insecticide formulation and treatment	Mean no. grubs/m 49 days after treatment	Mean no. grubs/m (range) at harvest	Mean field g/m (range) at harvest	Mean no. plant/m at harvest
Phorate (100 g/kg gran) 2 kg a.c./ha	2.7	3.2 (1.0–6.0)	199.6 (149.8–246.5)	10.7
Terbufos (100 g/kg gran) 2 kg a.c./ha	3.1	4.1 (2.7–5.3)	183.5 (150.7–252.5)	10.2
Chlorpyrifos (500 g/L e.c.) 2 kg a.c./ha	5.9	4.7 (1.7–8.0)	185.0 (134.6–271.2)	9.9
Chlorpyrifos (150 g/kg gran) 2 kg a.c./ha	6.3	7.0 (3.3–7.7)	152.5 (96.0–189.6)	9.6
Control (untreated)	6.3	5.6 (3.7–9.7)	173.5 (109.9–227.5)	8.9
LSD ($P = 0.05$)	2.9	n.s.	n.s.	n.s.

n.s. = not significant.

Regression lines relating yield to white grub numbers were calculated for each of the five treatments and the slopes and intercepts of the five lines compared. As there were no significant differences in either slopes or intercepts the data were pooled and a common regression calculated (Figure 1). Yield varied inversely with white grub numbers, the linear regression being: $y = 713.4 - 12.0\,x$ ($r = -0.75$, $n = 23$, $P<0.01$) where y is the weight of nut in shell per plot and x is the number of white grubs per plot (3 m of row) at harvest. An average density of one white grub per 3 m of row at harvest caused a yield loss of 44 kg/ha (assuming 11 000 m of row/ha).

As the larvae were present in the soil when the peanuts were planted it seems probable that the equation has some applicability as a predictive tool and future work could well aim at verifying this.

Maize trial, Atherton, 1981

Assessment 50 days after application showed that all three chemical treatments significantly ($P<0.05$) reduced white grub numbers (Table 2). Many recently killed larvae were recovered directly beneath maize plants in terbufos treated areas. In addition 36% of those white grubs recorded as alive from the terbufos treatments were moribund. The sampling trenches were wider than the chemically treated band and live white grubs were often found at the edge of the treated areas. Plants in the terbufos treated areas were significantly higher and heavier than those in the control. This advantage in plant growth continued to harvest when plots treated with terbufos at 2 kg a.c./ha outyielded the untreated controls by 0.985 t of grain/ha (Table 3). Although there were no differences in total plant populations between treatments there was a significant ($P<0.05$) decrease in the number of sterile plants in insecticide treated plots (2.5%) compared with untreated plots (9.1%) (Table 3).

There is no doubt that *Lepidiota* larvae can greatly reduce maize yields near Atherton but it seems unlikely that the number of larvae (1.34 per m) in the untreated area 50 days after planting could influence yield to the extent above. Although no pretreatment count was performed inspections before replanting revealed large numbers of white grubs. At sampling, diseased white grubs were recorded from the untreated areas and the survivors probably represented the tail of a larger population present when the crop was planted. Disease outbreaks were recorded among dense populations of white grubs on the Atherton Tableland by Smith (1937). Maize is planted sparsely at a density of 2.7 to 4.0 plants/m (I. C. Crosthwaite, pers. comm. 1987). In this trial it was grown at about three plants per metre so that even a few white grubs as large as those sampled (1 to 3 g) could severely damage the plants early in the growing period. Many very small stunted plants (<0.20 m) were present in the untreated plots 50 days after planting, probably the result of severe white grub attack.

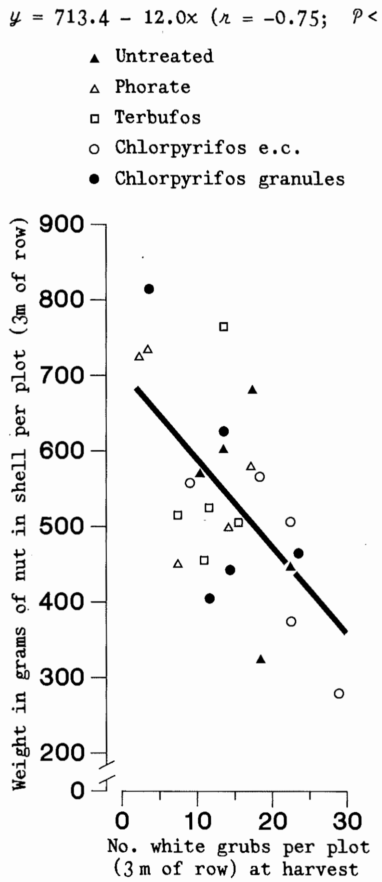

Figure 1. Relationship between white grub density at harvest and peanut yield at Atherton, 1979. Data are pooled from the following treatments: untreated, phorate, terbufos, chlorpyrifos e.c., chlorpyrifos granules at 2 kg a.c./ha.

Table 2. Effect of insecticides on number of white grubs (*Lepidiota* sp. probably *laevis*) and height and dry weight of maize plants, Atherton, 1981

Chemical formulation and treatment	Mean no. grubs/m 50 days after treatment	Mean plant height (mm) 50 days after planting	Mean plant dry weight (g) 50 days after planting
Terbufos (100 g/kg gran) 2 kg a.c./ha	0.32	751	41.6
Terbufos (100 g/kg gran) 4 kg a.c./ha	0.26	724	35.2
EBD (1930 g/L e.c.) 29 kg a.c./ha	0.33	n.a.	n.a.
Control (untreated)	1.34	520	19.7
LSD ($P = 0.01$)	0.56	49	14.9

n.a. = not available.

Conditions during this trial were particularly suitable for the action of the granular and fumigant chemicals. The soil was moist at application (18 mm of rain just before planting) and in the first month thereafter weekly rain falls of 80, 71, 101 and 73 mm were recorded. The tilth of the soil was fine and this, combined with high soil moisture, made an ideal seal to prevent the escape of EDB.

Table 3. Effect of insecticides on grain yield (at 14% moisture), number of sterile plants and total plant population in maize, Atherton, 1981

Insecticide formulation and treatment	Yield of grain (tonnes/ha)	No. sterile Plants/m	Plants/m
Terbufos (100 g/kg gran) 2 kg a.c./ha	3.822	0.060	2.98
Terbufos (100 g/kg gran) 4 kg a.c./ha	3.580	0.047	2.89
Control (untreated)	2.837	0.240	2.92
LSD (*P*=0.01)	0.634	0.15	n.s.

n.s.=not significant.

Peanut trial, Dimbulah, 1982

All chemicals except aldicarb significantly reduced numbers of white grubs (Table 4). Direct comparison with the Atherton trials is difficult because a different species of *Lepidiota* was involved and also the rate of chemical treatment was higher (3 kg a.c./ha *cf.* 2 kg a.c./ha). Nevertheless such good results were not obtained in the other trials reported here or on other trials on soil insects near Atherton (Gough and Brown, unpub. data 1979 to 1982). One possible explanation is that the chemicals were particularly effective in the Mulligan sands at Dimbulah. Nielsen and Boggs (1985) showed that soil insecticides were generally more toxic to first instar black vine weevil larvae in sand than in loam or muck, the LC_{50} increasing by about two to threefold in loam and up to 27 times in muck.

Table 4. Mean number of white grubs (*Lepidiota* sp.) in peanuts 54 days after application of granular insecticides at 3 kg a.c./ha, Dimbulah, 1982

Insecticide formulation	Mean no. white grubs/m
Ethoprophos (100 g/kg)	0
Fensulfothion (100 g/kg)	0
Isofenphos (50 g/kg)	0
Phorate (100 g/kg)	0
Terbufos (100 g/kg)	0.2
Aldicarb (150 g/kg)	1.7
Control (untreated)	1.2
LSD (*P*=0.05)	0.88

Observations in lodged maize, Tolga, 1982

The root systems of the lodged maize plants were attacked by significantly more white grubs than those of the upright plants (Table 5) and roots on the lodged plants were extensively pruned. This farm is exposed to the south east tradewinds and the reduction in the root system led to lodging in the windy period of mid May 1982. Lodging also occurs in sugar cane severely attacked by white grubs (Mungomery 1948).

Table 5. Comparison of numbers of second instar white grubs (*Lepidoptera* sp.) and grain yield (at 14% moisture) in one lodged and two upright stands of maize, Tolga, May 1982

Condition of crop	Mean no. white grubs/plant (±SE)	Mean wt (g) grain/5m of row (±SE)	Yield* tonnes/ha	Mean wt. (g) of whole cobs (±SE)
Upright—good stand	0.2±0.13	2400±175	5.28	n.s.
Upright—random	0.7±0.30	2092±144	4.61	233.1±11.9
Lodged—random	5.3±0.85	2057±80	4.53	246.0±10.9
LSD (P=0.05)	1.8	n.s.		n.s.

* Assuming 11 000 m of row/ha.

n.s.=not significant.

n.a.=not available.

Yield and cob size of the lodged plants were not reduced by the presence of larvae and the pruned roots (Table 5). This may be explained by the feeding habits of white grubs of which *L. frenchi* Blackburn is probably typical. The first instar lasts for about 60 days (Jarvis 1917) and during this time larvae subsist on organic matter rather than on living roots, as do many young white grubs (Wilson 1969*a*). That there was no reduction in yield before the maize reached physiological maturity at about 125 days after planting (Crosthwaite 1983) is therefore to be expected, as the larvae were generally too small to cause significant damage until the maize plants were nearly mature. Second instar larvae then caused damage to the root system as the plants senesced and harvest maturity was approached, resulting in lodging. No assessment of crop loss was made but the farmer experienced extreme difficulty in harvesting the lodged maize plants.

DISCUSSION

These data demonstrate that white grubs can cause substantial crop losses in areas of the Atherton Tableland. Experimental chemical control applied in line with commercial practice was successful using banded applications of terbufos at 2 kg a.c./ha. Rolston and Barlow (1980) and McBride (1984) also found terbufos to be effective against *Phyllophaga* spp. in the USA. Phorate, ethoprophos, fensulfothion and isofenphos showed promise, the latter three and terbufos also being effective against *Heteronyx* spp. (small white grubs with a one-year life-cycle) on peanuts in the South Burnett area of Queensland (D. J. Rogers and H. B. Brier, pers. comm. 1984). The failure of both formulations of chlorpyrifos was surprising as it has proved effective in slow release formulations against other *Lepidiota* larvae in sugar cane (Hitchcock *et al.* 1984). McBride (1984) found chlorpyrifos among the least effective chemicals in preventing stand losses in corn. Aldicarb was the only ineffective chemical in the Dimbulah trial and was also ineffective against larvae of white fringed weevil (*Graphognathus leucoloma* (Boheman) (Gough and Brown unpub. data). EDB has been used successfully against cicada nymphs attacking the roots of sugar cane (Chandler 1981).

As control is expensive, it is imperative that chemicals only be applied in areas where significant economic losses will occur. If the relationship between white grub density and yield in peanuts is correct, treatment would be warranted at, or above, average densities of about one larva per metre of row. In maize only very dense populations of white grubs may be worth treating.

Most damage is caused by one-year-old white grubs coming up from deeper in the soil to feed for a second year. The soil is often hard and dry during the fallow and sampling before planting may be difficult. However, it is possible to predict conditions under which the likelihood of attack is high. Thus crops planted in hastily prepared areas immediately after pasture when one-year-old white grubs may already be present are at risk. Crops in certain local areas are commonly attacked so that individual farms, including two of those above, are at risk year after year. Such sites were immediately adjacent to large areas of pasture from which adult beetles flew in to oviposit in newly planted crops. This behaviour is not restricted to *Lepidiota* spp. and was recorded for white grubs in the USA by McBride (1984).

The attractiveness of peanut plants as oviposition sites should be examined. In the Atherton trials, both the infested maize and peanut crops followed peanut crops in which the eggs were laid a year earlier. The maize crop attacked by younger second instar white grubs initially contained an extremely high density of peanut volunteer plants although these were subsequently destroyed by disease. The attractiveness of peanut plants for some melolonthids was well demonstrated by *Heteronyx piceus* Blanchard near Rocky Creek. Adults hid in the soil at the base of the plants where the eggs were laid, emerging at night to feed on the foliage (Gough and Brown unpub. data 1979). The preference for peanut foliage was again shown at this site in the summer of 1980 when half a uniform field was sown to peanuts and half to maize. A large beetle population emerged in the maize which was an unsuitable diet. They moved out to feed and where the two crops met the peanut plants were completely defoliated. *H. piceus* also occurs in the South Burnett where adults have a similar behaviour in peanuts (D. J. Rogers and H. B. Brier, pers. comm. 1987).

Attempts to predict the sporadic attacks by white grubs must take into consideration the two-year life-cycle. Adult emergence from the soil depends on rainfall in the period from September to December. Smith (1936) examined rainfall records for a series of odd and even years. He showed that a dry spring could prevent adult emergence and severely reduce subsequent populations of white grubs in that series. The population of white grubs would then take some years to build up. At the same time, the population one year out of phase was often high because two very dry springs in succession are rare on the wet tablelands. This two year pattern was evident on the farm near Atherton where heavy attacks occurred in 1979 and 1981. When these crops were sampled, almost all the white grubs were third instar, suggesting that beetle flights and egg laying occurred in late 1977 and 1979 but not in late 1978 and 1980.

Positive identification of the species of *Lepidiota* in this study proved impossible as white grubs collected in crops and removed to the laboratory for rearing died of fungal or mite infections before adult emergence. However, circumstantial evidence exists as to their specific identity. Third instar larvae collected from the extensive infestations in maize and peanuts near Atherton could not be separated from those of *L. frenchi*, yet it seems unlikely they belong to this species but rather *L. laevis*, the larvae of which have not been described. Adults of both species (and therefore their larvae) are of similar size. Light traps on this farm yielded only *L. laevis*, which is recorded as a major pest of pastures in a very restricted area, including the farm in question (Atherton 1939). Extensive collections of *Lepidiota* spp. from Atherton made by J. H. Barrett and others commonly include *L. laevis* but *L. frenchi* is absent (QDPI Collection). *L. frenchi* was recorded from Mareeba and near Ravenshoe but not from Atherton (Britton 1978). The species of *Lepidiota* near Tolga and at Dimbulah are not known.

Because of the sporadic nature of attack, data on control and yield losses are difficult to acquire. This paper may contribute to a more complete study in the future. Chemical control of white grubs on the Atherton Tableland clearly is possible. Treatment of maize is warranted when white grub numbers are very high, but a more accurate assessment of the influence of grub density on yield is needed. This study has dealt mainly with crops in continuously cultivated areas, however, attention should be given to white grub damage in areas near Atherton where maize is planted immediately following pasture. In peanuts, future work should aim at verification of the economic thresholds proposed above.

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