Polyphylla fullo L. (Col., Melolonthidae) in the dunes

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Summary

The grubs of *Polyphylla fullo* L. annually cause considerable damage to newly planted sites in the dunes near Meijendell (Wassenaar). The grubs are mainly found in the Tortuleto Phleetum community where the sand is moist during summer. A sand-moisture content of between 10.9 and 18.9 % is preferred. In this moist sand the grubs may progress as far as 25 cm a day. In dry sand they show little or no movement, at the most 10 cm a day. While moving through the sand they maintain a cell filled with saturated water vapour (HAVELOCK FIDLER, 1936).

The grubs appeared to be able to detect moisture and roots at a distance of about 15 cm, and can distinguish between the roots of different plant species.

Roots dipped in a ¼ % *lindane* emulsion were accepted in dry sand but rejected in moist soil.

Lindane emulsion appears to seep very slowly in dune sand, *e.g.* 10 cc of an emulsion poured over a surface of 100 cm2 caused no detectable disturbance to the grubs after 10 weeks of regular watering. It is generally known that chlorinated hydrocarbon insecticides are adsorbed by soils, particularly in clays and in soils with a high content of organic material.

The grubs showed a preference for certain plant species (TABLE 2). It is advisable to plant these threatened species in a contaminated and sparsely overgrown area with insecticidal protection. Plant species that are only occasionally attacked can probably be planted in a contaminated area without such protection.

In laboratory experiments 4th-instar grubs appeared to be more susceptible to *lindane* than to the other tried compounds, mortality commencing only after 2 weeks (TABLE 3). In a field experiment *Aldrin* proved to give better results than *lindane* (TABLE 4). In these experiments dusts gave better results than emulsions, but much larger amounts of active ingredient were used.

The high percentage of saplings killed by grubs during 1959 may be due to the dry summer. The grubs were probably in such need of moisture that they overcame their aversion to the treated roots. Possibly many grubs were killed, so that the planted trees were only slightly damaged during the next two seasons.

In the second field experiment *Aldrin* emulsion was used exclusively. All planted saplings were dipped, but in a few plots the trees were also given ¼ litre of ¼ % *Aldrin* emulsion, added in the planting hole. This addition resulted in about the same protection as dusts might have given (TABLE 5) in the first field experiment.

1. Introduction

For many years the grubs of this scarabaeid beetle have been a nuisance in the dunes of the Hague waterworks at Meijendell, near Wassenaar (FIG. 1). The species is found almost exclusively in the Tortuleto Phleetum community. This pioneer community gives a poor ground cover, the most common plant species being Bent grass (*Ammo-*

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phila arenaria LINK.), Bedstraw (*Galium verum* L.), Wallpepper (*Sedum acre* L.), Rest-harrow (*Ononis repens* L.) and Sand sedge (*Carex arenaria* L.). On the southern slopes of the dunes in particular this community gives rise to open bushes of Sea buckthorn (*Hippophae rhamnoides* L.) with Creeping willow (*Salix repens* L.), Privet (*Ligustrum vulgare* L.), Hawthorn (*Crataegus monogyna* JACQ.) and Briar rose (*Rosa canina* L.) interspersed with a solitary birch (*Betula* sp.) or Oak (*Quercus robur* L.) (BOERBOOM, 1958).

Every year several such sites are planted at Meijendell with saplings of birch, hawthorn, oak, poplar and rose. These saplings are usually damaged and partly destroyed by the grubs.

The grub has been mentioned in other countries as being a pest on poor soils. GRUND (1909) recalls the occurrence of the beetle in N.E. Bohemia. Here the species occurred on poor sandy soil in decaying plantations of Scots pine, oak and birch.

In the dunes near Meijendell the damage usually begins to be noticeable in the second half of May when the damaged trees wilt, and this damage lasts to October or the beginning of November. The affected trees are bitten through at the root collar or the tap-root; even roots of more than 1 cm diameter are cut. The grubs may also eat along the length of a root and the latter may be girdled (FIG. 2). Trees having a diameter of over 10 cm at the foot may be killed by a constant attack of the grubs every year.

The damage usually occurs at a depth varying from some centimetres to more than half a metre. Practically all plant species may be attacked. The damage, however, is not equally severe in all plant species, and may vary considerably from year to year and from one site to another. Experimental excavations at Meijendell showed that severely infected plots usually contained only about one grub per square metre. This is the same as the number given by SPEERS and SCHMIEGE (1961) in the U.S.A. for the grubs of *Polyphaga* sp., a relative of *Polyphylla*. Owing to the persistent damage an effective control was very needful. Since this is a catchment area of water for the waterworks a prolific use of modern persistent pesticides is out of the question. Care must therefore be taken to limit the use of these compounds.

2. The life cycle of the beetle

The beetles are in flight in July. They are seldom seen during the day and seem to pass the time in a secluded spot. According to GRUND, however, the beetles emerge from the soil in the evening and fly to the canopy of trees where they eat the leaves and copulate. Some hours later they fly back to the site of emergence and dig themselves in again.

Nothing is known about oviposition. When beetles were reared only a few eggs were layed. These had a very soft shell which broke readily. None produced offspring.

During the development stage the grubs stay in the soil. They make themselves a cell by pushing the sand with the back and legs. In season, the grubs live at a depth of 5 to 20 cm and feed on the roots of many plant species. During the autumn cold makes them move to a greater depth to a site where they overwinter. In April they reappear in the top soil.

There is insufficient data on the number of years required for the grubs to become full-grown. According to GRUND the life-cycle in Bohemia is 3 to 4 years. The grubs reared by us did not develop readily so that we were unable to obtain direct information. We did obtain information on the number of instars and the dimensions

of the head-capsules in the different instars. However, we probably overlooked the newly-hatched grubs. We found grubs of the 2nd, 3rd and 4th instar, and the head-capsules had diameters of respectively 2.5—3.9, 4.8—5.9 and 8.3—10.1 mm.
TABLE 1 was compiled by recording the diameters of the head-capsules of the grubs found in the dunes during different months in the course of our investigations.
The percentages of the different instars found during successive months are given in FIG. 3. It can be seen that each instar has one peak a year. It might therefore be concluded that each instar takes a year to develop. The first instar has not been found, but as the eggs are laid in July and the number of 2nd-instar grubs increases in May, we may conclude that the development of egg + 1st instar lasts from July to May. The total development might therefore be put at four years. The grubs pupate in the soil in June, and the beetles are in flight in July.

TABLE 1. The occurrence of grubs in the dunes in successive months

Month	2nd instar		3rd instar		4th instar		Total
	No.	%	No.	%	No.	%	No.
Jan.	13	39	8	24	11	33	32
Feb.	8	11	16	24	43	65	66
March	2	10	5	25	14	68	21
April	5	20	11	44	10	41	26
May	7	28	11	44	7	28	25
June	21	75	7	25	0		28
July	14	13	17	16	65	63	96
Aug.	14	53	3	12	9	36	26
Sept.	3	6	4	11	30	82	37
Oct.	4	12	11	33	19	57	34
Nov.	2	12	5	34	9	54	16
Dec.	0		3	25	9	75	12
Nov.—Feb.	22	17	32	25	72	56	126

FIG. 3. Percentage of various instars found in the dunes in successive months

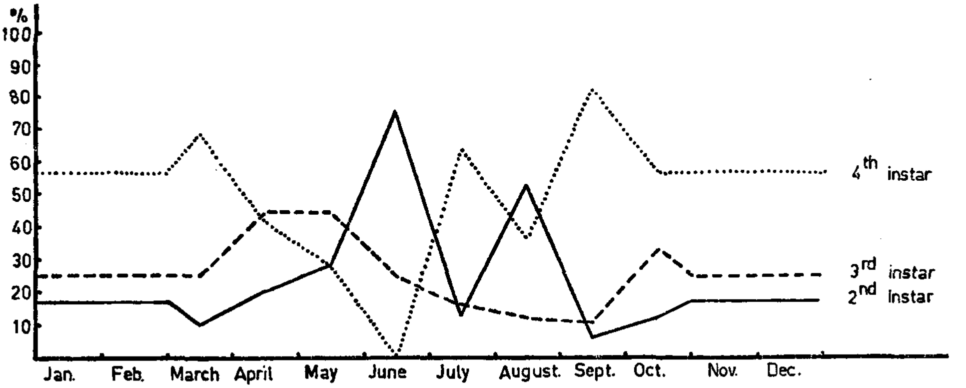

FIG. 1. A grub-infected site in the dunes

FIG. 2. Damage caused by grubs to tap-roots of various tree species

3. Moisture preference of the grubs

The moisture content of sand in the dunes may vary. Experiments were carried out in order to determine the moisture preference of *Polyphylla* grubs.

Slanting buckets containing some water were filled with oven-dry sand. Thus the lowest part of the buckets contained saturated sand, the top consisting of oven-dry sand. A number of grubs were placed on top of the sand and the grubs dug out a week later. Care was taken to collect the sand surrounding the grubs and the moisture content of this sand was determined. It varied between 10.9 and 18.9 % of the weight of oven-dry sand.

In order to observe the mutual influence of food preference and moisture preference grubs were kept in frames consisting of two 50 × 50 cm glass plates standing 2 cm apart in a wooden frame. The frames were filled with alternate vertical columns of dry and moist dune sand. A birch sapling was planted in each column and a grub placed at the bottom. Owing to the lack of space between the glass plates the grubs and part of the roots could easily be observed. By frequently noting the position of the grubs on the glass walls it was found that the animals consistently crawled to the moist sand columns first and only approached the roots afterwards. When put into frames with dry sand only, the grubs were much less lively than those in moist sand. They did not progress more than 10 cm a day, as against about 25 cm a day in the moist sand. The grubs in the dry sand were greatly hindered by repeated collapsing of the cell walls. Dry sand is therefore an unsuitable environment for the grubs. Moreover, according to HAVELOCK FIDLER (1936) in a dry environment they perspire profusely in order to keep the atmosphere in their cells saturated with water vapour and thus eventually lose too much moisture.

4. Food preference of the grubs

In the experiments carried out with the glass frames it was found that the grubs preferred the roots of certain trees to those of other plant species. Since this knowledge will probably be used for the control of the grubs it was necessary to find out which plant species are preferred and which rejected.

Two different species were planted in large flower-pots. The roots of these plants were interwoven. Three 3rd-instar grubs were added to each pot. Root damage was checked after two weeks. In this way a comparison was made between 18 species which are common in the dunes. There were five replicates of each plant combination. In some cases none of the plants were eaten, in others both species were accepted. Each species was presented 85 times. TABLE 2 gives a survey of the results.

The advanced season should probably be blamed for the large number of times on which none of the plant species were damaged. The table shows that *Calamagrostis, Ammophila* and *Ononis* were by far the most preferred species. Damaged bushes of *Ammophila* may be sporadically encountered in the dunes. But the damage is not spectacular. In the dunes *Calamagrostis* lives in surroundings which are too wet for the grubs. Birch, Aspen, Oak and Creeping willow were eaten readily but Black poplar, Gray poplar, White poplar and Rose species are clearly damaged less often than the two other groups. Hawthorn, Sea buckthorn and Privet are only occasionally damaged.

Laboratory observations were made on the manner in which the grubs reach the roots of the plants. They appear to dig through the sand at random and when they

TABLE 2. Frequency of attack in preference trials

	Number of cases in which			
	both species are attacked	only the species mentioned is attacked	the accompanying species is attacked	neither species is attacked
Calamagrostis epigeios	19	36	3	27
Restharrow (*Ononis repens*)	25	21	2	37
Bentgrass (*Ammophila arenaria*)	20	23	5	37
Trembling aspen (*Populus tremula*)	15	24	9	37
Berch spp. (*Betula pendula* and *B. pubescens*)	22	18	9	36
Oak (*Quercus robur*)	16	23	14	32
Creeping willow (*Salix repens*)	24	14	9	38
Black poplar (*Populus nigra*)	19	18	15	33
Grey poplar (*P. canescens*)	13	21	19	32
Sand sedge (*Carex arenaria*)	11	21	17	36
White poplar (*Populus alba*)	14	19	16	36
Rose sp. (*Rosa pimpinellifolia*)	15	13	20	27
Hawthorn (*Crataegus monogyna*)	21	4	25	35
Sea buckthorn (*Hippophae rhamnoides*)	14	7	29	35
Privet (*Ligustrum vulgare*)	12	5	29	39
Koeleria albescens	8	6	15	56
Hound's tongue (*Cynoglossum officinale*)	8	4	31	42
Corynephorus canescens	6	2	16	61

encounter a root they may follow it to the tap-root. Sometimes they eat all along the route and sometimes only after reaching the larger roots.

5. The occurrence of the grubs in the dunes

The reason for the occurrence of the grubs in the Tortuleto Phleetum community now begins to be clear. After a period of drought in summer, the sand underneath bushes is very dry up to a considerable depth, and sand of sparsely overgrown soil is then still moist enough for the grubs. Underneath bushes the grubs might find suitable living conditions during extremely wet seasons only and as their life-cycle is four years, there is no great chance that the weather will be wet for four successive summers. This is probably the reason why we never found any grubs of this species in the sand underneath bushes during summer. But they occurred fairly frequently in sparsely covered parts.

6. Control of the pest

It may be concluded from the above observations that control will probably only be useful when sparsely covered sites are to be planted with small saplings. In this case suitable food is provided at sites abounding in the grubs. A disaster might be prevented by planting the saplings very close together in order to increase soil evaporation, thus making the sand unsuitable as a habitat. But even then we might expect serious damage before the grub population has decreased sufficiently. In this case also initial damage should be prevented by the use of pesticides.

6.1. Laboratory experiments

The susceptibility of 4th-instar larvae was determined in the laboratory with a number of insecticides. It is these last-instar grubs that cause most damage and are the least susceptible to the different compounds. Hence a dosage which kills the large grubs will also exterminate the smaller instars.

We knew the grubs to be susceptible to *lindane*. There were two alternatives, *viz.* pouring the emulsion over the soil or dipping the roots. Both methods were compared in dry and moist sand. For this purpose we used the glass frames again.

A first pair of frames was filled with dry sand, in a second pair we used moist sand, while the third pair contained four alternate columns of moist and dry sand.

The frames of the two first-mentioned pairs contained four birch saplings each and four last-instar grubs. These saplings were alternately dipped in water or a ¼ % *lindane* emulsion. The soil surface of the third pair of frames (= 50 × 2 cm) was sprinkled with 10 cc of a ¼ % *lindane* emulsion.

Grubs in the frames filled with dry sand did not hesitate to eat the roots and grubs which consumed the roots of trees dipped in the *lindane* emulsion exuded after a few days a red fluid which stained the surrounding sand. Eleven days later these grubs were dead.

In the frames containing moist sand the grubs acted differently. Either they did not move or fed on the untreated roots. A possible explanation of this phenomenon might be that the grubs detect *lindane* in moist soil but are unable to do so in dry soil. Another explanation might be that the need for moisture in dry sand outweighs their aversion to *lindane*.

In the third pair of frames the grubs did not appear to be injured by the *lindane*. The sand was watered regularly to see whether the compound would seep downward under the effect of the water. The experiment lasted ten weeks, during which time all the grubs remained healthy and lively. It may therefore be concluded that pouring the insecticide over the soil is not effective as a control measure.

We then compared the responses of grubs kept with roots dipped in an emulsion with those kept with roots in a mixture of sand and insecticide emulsion. Five 4th-instar grubs, each kept in a ½-litre glass jar, were used for each treatment. In the first series the sand in each jar (400 cc) was mixed with 5 cc of a ¼ % emulsion.

In the second batch the roots of the planted saplings were dipped in the emulsion, the sand not being treated. The score is given in TABLE 3.

TABLE 3. Results of the use of various insecticides in laboratory experiments

Treatment	No. of weeks elapsing before death of		Mean life (weeks)	Mortality rate
	1st grub	last grub		
Sand mixed with ¼ % emulsions				
Lindane	3	4	3.4	6.10
Aldrin	2	14	6.0	4.03
Chlordane	3	14	8.6	2.32
Dieldrin	3	16	7.2	2.15
Heptachlor	3	17	9.0	2.14
Water	14	19	16.2	0.89
Roots dipped in ¼ % emulsions				
Lindane	2	6	3.8	9.95
Aldrin	7	15	12.2	1.27
Chlordane	4	15	9.2	2.32
Dieldrin	4	10	6.8	2.36
Heptachlor	6	17	9.4	1.67
Water	14	15	14.6	0.97

The mortality rate in this table was calculated according to the formula:

$$\frac{\Sigma\ 100/s}{n} = S$$

in which S denotes the mortality rate
s = life-term of each grub in days
n = number of grubs

The grubs appeared to be most susceptible to *lindane* but even with the liberal amounts applied in the first series, the mean life-term of the grubs was still several weeks. We gave up further experiments with heavier doses, also because of the risk involved in the dunes where drinking water is extracted.

6.2. The first field experiment

Two field experiments were carried out to determine the possibility of applying in the dunes the results obtained in the laboratory experiments. The first was started in February and March, 1959. *Lindane* and *Aldrin* were used in the form of emulsions and dusts. The emulsions had an ¼ % active ingredient in which the roots of the saplings were dipped. The dusts were mixed with sand and applied to the planting holes. *Lindane* dust of 0.7 % a.i. was used at the rate of 38 g per hole and 12.5 g of 2.5 % *Aldrin*. The saplings used were birch, hawthorn and rose.
A number of plots were laid out in a sparsely overgrown part of the dunes which was expected to harbour a great many grubs. Each plot was planted with one plant species. Thus the damage inflicted was not a matter of free choice of the grubs but depended on the number of grubs initially present.
In the course of 1959 about 48 % of the treated saplings and about 29 % of the untreated trees were dug out and examined for damage. Because the trees were very small it might be assumed that a damaged plant was certain to die. These damaged plants were therefore considered to have been killed already. The next winters all the dead plants were checked and the cause of their death determined. In addition to grub damage casualties were also caused by rabbits and drought. In TABLE 4 the percentages of the trees killed by rabbits and other causes are calculated yearly from the number of healthy trees present at the beginning of the year. The mortality percentage caused by the grubs was calculated from the number of healthy trees, *i.e.* after subtracting the number of trees killed by other causes as the grubs never were seen to attack decaying trees.
It is noticeable that the percentage of trees killed by rabbits and other causes was very high in 1960. The percentage of trees killed by grubs was smaller during the last period than during 1959. The same applies to the untreated trees. The need for moisture during the dry summer of 1959 probably outweighed the aversion to treated roots, thus causing a heavy mortality among the grubs. Hence the remaining larvae were only capable of causing little damage during the following years.
Contrary to the results of the laboratory experiments, *Aldrin* proved to be more effective in the field. In general, the dusts gave better results, but the amounts of active ingredient were also greater. However, the dusts required too much labour. It might be more economical to use granular insecticides of a low dosage so that a fair amount of granules can be readily apportioned to each planting hole. The granules might also retard seeping of the compound with rainwater.

TABLE 4. Results of the use of lindane and aldrin in the dunes (1st experiment)

Treatment	1959	1960	1961	1962
Lindane emulsion				
Living trees at beginning of the year (number)	578	426	174	155
Trees killed by rabbits and other causes (%)	18	57	5	
Trees killed by grubs (%)	10.7	5.4	6.6	
Lindane dust				
Living trees at beginning of the year (number)	578	464	184	178
Trees killed by rabbits and other causes (%)	14	60	3	
Trees killed by grubs (%)	6.8	0	0	
Aldrin emulsion				
Living trees at beginning of the year (number)	578	463	208	191
Trees killed by rabbits and other causes (%)	12	54	6	
Trees killed by grubs (%)	9.4	2.8	2.6	
Aldrin dust				
Living trees at beginning of the year (number)	578	495	208	194
Trees killed by rabbits and other causes (%)	12	58	6	
Trees killed by grubs (%)	2.6	0.5	0.5	
Not treated				
Living trees at beginning of the year (number)	7633	4762	2300	1446
Trees killed by rabbits and other causes (%)	19	47	6	
Trees killed by grubs (%)	23.0	4.1	5.1	

6.3. The second field experiment

In this case only ¼ % *Aldrin* emulsion was used. The roots of all plants were dipped, but in a few plots the trees also received ¼ litre of the liquid in the planting hole (TABLE 5).

Addition of the emulsion to the planting hole considerably decreased the grub attack. The drawback of this method is the great amount of water that has to be carried to the dunes, which makes it too expensive.

TABLE 5. Results of the use of aldrin in the dunes (2nd experiment)

	1960	1961
Dipped + ¼ litre of emulsion in planting hole		
Living trees at beginning of the year (number)	700	659
Trees killed by rabbits and other causes (%)	5	4
Trees killed by grubs (%)	0.6	0.2
Dipped only		
Living trees at beginning of the year (number)	700	640
Trees killed by rabbits and other causes (%)	6	5
Trees killed by grubs (%)	9.5	5.6

7. Conclusions

These experiments show that it is quite possible to reduce the loss of trees to 1/3 merely by dipping the roots before planting. The addition of *Aldrin* dust to the planting hole will eliminate practically all damage by grubs.

When this treatment is combined with narrow planting in order to obtain a closed plant cover within a few years, a reasonably good result may be expected without serious loss of plant material. Vegetation growth might be accellerated by using fertilizers, dung or compost.

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