SOME BIOLOGICAL CONTROLLING FACTORS OF THE CABBAGE ROOT FLY (*Erioischia brassicae* (Bouché)) IN SOUTH-EAST SCOTLAND AND THE EFFECTS THEREON OF THE USE OF CERTAIN INSECTICIDES

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INTRODUCTION

Since insecticides have been introduced for the control of agricultural pests, remarkable achievements have been obtained. Harvests have been greater and the quality of the crops much improved. Some of the advantages of the use of chemicals for the control of pests are their availability at all times since they can be stored for long periods of time without losing their effectiveness, the speed at which they operate and, normally, the reliability of their lethal effect on insect pests.

On the other hand, repeated use of insecticides has caused hazards which cannot be overlooked. The development of resistance to insecticides seems to be the major and most alarming factor of our modern system of insect control. Pest problems that appeared to have been solved a few years ago are with us anew with more serious implications. Continuous killing of the pest's natural enemies in our fields is an important hazard and one which has often been neglected until recent years. The effect of this factor is most significant when resistance arises and the natural enemies are not there when they are most needed. Persistent use of pesticides can also produce harmful effects on soil fauna, beneficial insects, agricultural crops and on stock and wild animals, which cannot be overlooked. These effects are summarised by the author in a thesis submitted to Edinburgh University in 1965. Cabbage root fly strains resistant to organochlorine compounds are reported from England and from several other parts of the world. Parasites and predators of the root fly which are known to reduce the pest population considerably, are reported to be killed and reduced in number in fields where there has been extensive use of insecticides.

However, in spite of all the disadvantages and side effects of the chemicals, they are still providing the key to the control of insects. New methods of use, therefore, are needed mainly to overcome these harmful effects.

Entomologists are suggesting the integration of all known cultural, biological, ecological and chemical methods in such a way as to obtain the maximum total benefit and especially to minimize the harmful side effects that may result from exclusive use of chemical pesticides.

REVIEW OF LITERATURE

The natural mortality of the cabbage root fly

(a) During the egg stage:

Predatory beetles, mainly belonging to the Carabidae and Staphylinidae, are known to feed on the egg stage of the cabbage root fly and are considered by many authors to be an important agent in the reduction of the pest populations. Predation on the egg stage of the cabbage root fly has been examined by many research workers in the laboratory and in the field. Miles (1952) noticed some irregular holes in the sides and ends of root fly eggs and suggested that the damaged eggs had been devoured by some predatory animal. Wishart et al. (1956) compared the destroyed eggs after attack by certain predators and showed that ground beetles usually devoured the eggs entirely, but occasionally left pieces of the chorion after the liquid contents had been removed. Staphylinidae pierced the eggs with their mandibles and after sucking the contents, left the chorion in a shapeless mass. Mites were found to leave the chorion in the original shape but caused a gaping hole in it. Hughes (1959b) mentioned that these kinds of damaged eggs are comparable in every way with those collected from the field.

Predation on the egg stage was also observed by placing stained eggs in groups around plants in the field (Wishart et al. 1956). The percentage of eggs carried off or destroyed was calculated, the greater losses occurring during the first 24 hours than during subsequent periods. This was attributed to the variation in availability of the eggs to the predators, and whether the eggs occurred close together or singly. A similar technique was used by Hughes (1959b), except that the eggs were unmarked, and were identified by placing each group in a certain manner near the stem of the plant. The result of this experiment indicated that an average of 42% of the eggs were lost every day.

The same author criticised this method and established a more direct technique based on estimating the egg losses directly from egg counts at 2 and 4 days intervals. He then compared the proportion of eggs eaten with the daily records of numbers of predatory beetles captured in the same field. The results of this comparison suggested that a linear relationship applied, expressed by the regression equation:- Egg loss = predator count x 0·0136.

To determine the importance of predatory beetles in the natural control of the cabbage root fly, experiments were carried out by Wright et al. (1960) using various types of barrier to obtain different levels of beetle populations on cauliflower plots. A straw barrier treated with D.D.T. resulted in a lower Bembidion lampros (Herbst) population density, and a catch-barrier treatment resulted in a larger one. Egg counts indicated that there was a negative correlation between the total number of eggs and the number of beetles recorded in each treatment. These results were directly reflected in the crops, as the straw-barrier D.D.T. treatment gave the lowest yield and the catch-barrier treatment resulted in a slightly better performance than the untreated plots. This work was continued in a more detailed way by Coaker (1965). The cumulative egg counts were found to be inversely related to the number of Carabidae trapped. This result was similar to that obtained by Wright et al. (1960) when only B. lampros was considered. By including all predatory Carabids trapped, an improvement in this relationship was obtained by multiplying the numbers of each predatory species by their relative predatory value (Coaker and Williams, 1963). The aggregate predatory scores showed a discrepancy when compared with the related root fly egg numbers. This was attributed to other mortality factors affecting egg survival, such as predation by Staphylinid beetles. Coaker (1965) has noticed an increase in the root fly egg survival in the later part of the first generation. This increase was related partly to the fewer B. lampros on the plots and partly to the increased cover which was provided by the more mature plants, and which B. lampros finds unattractive. Mitchell (1963) mentioned that in the second generation predation was greater in the later part of the attack. This may have been related to the increased plant cover, as additional shading favours Harpalus rufipes (Degeer), Feronia spp. and Trechus spp., which were more common at that time of the year. Population estimates of the immature stages of the cabbage root fly were carried out by Hughes and Salter (1959a). Ninety-five per cent of the individuals died during development. The major losses occurred in the egg and the pupal stages. The egg mortality was attributed to predation, reduced egg viability, adverse weather at hatching. Egg predation accounted for no less than 85·7% of the total mortality (Hughes, 1959b). Coaker and Worrall's (1961) calculation fell between 60-70%.

Different species of Carabidae and Staphylinidae are reported as predators on cabbage root fly from various parts of the world.

From Canada it was reported by Wishart et al. (1956) that the Carabid Bembidion quadrimaculatum appositum Say., was the most important predator of the cabbage root fly egg stage. The species Bembidion nitidum (Kby.) and Agonoderus lecontei Chd. were common and were stated to have an intermediate egg-eating capacity. Agonum sp., Bembidion sp. and Tachyura incurva (Say) were scarce but had large, intermediate and low egg-eating capacity respectively. Among the Staphylinidae, Philonthus spp. were common and had a large egg-eating capacity. Aleochara bilineata (Gyll) and Gyrohypnus hamatus (Say) were scarce and they too had large and intermediate egg-eating capacities respectively. Wright et al. (1956) emphasised the importance of the part played by predatory beetles in reducing the natural population of the cabbage root fly in the Wellesbourne area. He stated that more than thirty species of beetles, chiefly belonging to the families Carabidae and Staphylinidae, would eat the eggs, larvae or pupae of the root fly when offered them in the laboratory. One individual of B. lampros consumed 428 eggs, 159 first instar larvae and 3 third instar larvae over a period of six months. Coaker and Williams (1963) reported that B. lampros and Harpalus aeneus (F.) were regularly predominant during the first generation of the root fly in April and May, while B. quadrimaculatum, H. rufipes, Feronia vulgaris (L.) were the most common during the second generation in June and July. Among the Staphylinid species A. bilineata, A. bipustulata (L.) and Oxytelus rugosus (F.) were the most common from April to August. The predatory value of the Carabid and Staphylinid beetles was also shown by the same authors by two different methods. Among the Carabidae, B. lampros and

Trechus obtusus Erichson were shown to be the most efficient predators.

(b) During the larval and pupal stages:

The cabbage root fly larvae and pupae in the field are exposed to the attack of many natural enemies. Wadsworth (1915a) mentioned that at least twenty per cent of the fly larvae and pupae are destroyed by Coleopterous and Hymenopterous parasites.

Hymenoptera belonging to Braconidae, Cynipidae and Ichneumonidae are reported to attack the larval stages of the cabbage root fly. Of these the Cynipid Idiomorpha rapae(Westd.) is recorded to be the most important parasite (Schoene,1916 in U.S.A., Glison and Treherne, 1916 in Canada and Smith, 1927 in England). The female of I. rapae oviposits in the first or second instar larva , the host dying during the pupal stage (James, 1928). Two main periods of emergence of the parasite are reported by most workers, one in April and May, and the second in late August and September. Wishart and Monteith (1954) mentioned that the number of generations per year depends on the development of the host. James (1928) found that the incidence of parasitisation by I. rapae is about 25% in the Cambridge district. Smith (1927) recorded 30% in Lancashire and Cheshire.

Parasitism by A. bilineata (Coleoptera, Staphylinidae) is recorded by most of the authors cited above. The life history of this parasite was studied by Wadsworth (1915b), the eggs are deposited in the soil and the hatched larvae burrow downwards in search of cabbage root fly pupae. The parasite larva then enters the puparium, feeds on the pupa, causing its death. Read (1962) reported that the larvae produced by one female A. bilineata parasitise an average of 230 cabbage root fly pupae, and mentioned that the parasite develops slower in the field than Erioischia brassicae (Bouché), and that the latter would produce first generation larvae before the parasite became available. Abu Yaman (1960) in Holland reported that the percentage parasitisation by I. rapae plus A. bilineata was 33·9, 37·4 and 32·4 for the first, second and third generations in 1957, and 21·5, 20·4 and 27·6 in 1958.

Mortality in the larval stage is also caused by predatory beetles (Gibson and Treherne, 1916; Read, 1962), and ants (Schoene, 1916). The larva of the Anthomyiid Phaonia trimaculata Bouché is also reported by Smith (1927) to feed on cabbage root fly larvae.

(c) During the adult stage:

Predation on the cabbage root fly adults by Anthomyiids and by the entomophagous fungus Empusa musca is reported by Schoene (1916). The Cordylurid Scatophaga stercoraria (L.) is reported by Hobby (1931) to be a predator of E. brassicae in England. Read (1958) in Canada reports that the predator was often more abundant than E. brassicae in the field and mentioned that as many as three flies were destroyed in a day by one specimen.

The effect of insecticides on the parasites and predators of the cabbage root fly:

Since the importance of predators and parasites in the control of the immature stages of the cabbage root fly was established, more knowledge of the effect of insecticides on these predators and parasites was required so that recommendations could be given to keep such losses to a minimum. Wright et al. (1956) and Hughes et al. (1959) mentioned that the treatment of soil with certain insecticides, broadcast at low rates, resulted in increased root fly infestation, and lower yields of cabbage. Morris (1960) showed that a furrow application of granulated heptachlor or aldrin at 2 lb. toxicant per acre has eliminated the Staphylinid parasite A. bilineata and reduced parasitism of the pupae by the Cynipid Trybliographa rapae (Westw.) from 9% to less than 2%. Read (1960b) showed that heptachlor and parathion each applied at 5 lb. toxicant per acre in 6 inch bands on both sides of the turnip rows resulted in an 80% and 23% reduction in the number of parasitised puparia respectively. Read (1964) showed that two years after the introduction of insecticides, parasitism in untreated areas of the field had dropped from 90% to approximately 10% and the surviving pest has increased accordingly. An experiment by Wright et al. (1960) showed that a dieldrin treatment applied at 80 c.c. drench of 0·03% dieldrin emulsion per plant, caused a 51·4% reduction in the number of B. lampros trapped compared with the untreated plots. Laboratory studies by Mowat (1964) showed that the smaller Carabidae species, e.g. Trechus quadristriatus

(Schrank). were affected by lower concentrations of dieldrin in the soil (0·7 p.p.m.) than were the larger species, e.g. F.vulgaris (1·8 p.p.m.) and H. aeneus (1·7 p.p.m.). Field experiments by Coaker (1966) showed that residues of aldrin and dieldrin in the soil have altered Carabid and Staphylinid predator populations. Aleochara spp. were the most susceptible, being killed by concentrations of less than 0·1 p.p.m. dieldrin in the soil. B. lampros, B. quadrimaculatum and T. quadristriatus showed an initial phase of increase in activity with concentrations less than 0·5 p.p.m. dieldrin, followed by a reduction in numbers. H. aeneus and Feronia melanaria (Illiger) were less susceptible. The percentage parasitism by I. rapae, A. bilineata and A. bipustulata was decreased by the insecticide residues, the latter two species being more affected.

Duration of the annual attack of E. brassicae:

The cabbage root fly E. brassicae is reported from many countries in Europe, North U.S.A. and Canada as a pest attacking cruciferous crops. The onset of attack by the cabbage root fly and the number of generations occurring annually seems to vary from one country to another. Brittain (1927) in Canada mentioned that eight out of ten years, eggs were first deposited during the last week in May and the remaining two during the first week of June. Swailes (1958) recorded two generations of the fly in Southern Alberta, Canada. Lein (1955) in Norway mentioned that oviposition by E. brassicae begins in late May or June in the extreme south and in June elsewhere and recorded two generations a year. Lundblad (1933) in Sweden reported that there are at least two generations. Wagn (1954) in Denmark mentioned that the flies emerge in late May or early June and reported up to three generations a year of which the first is the most harmful. Carlson _et al_. (1947) in Washington, U.S.A. reported four or five generations a year and mentioned that the flies emerged during the first two weeks of April. MacDougall (1913) in Scotland reported that the first flies are seen towards the end of April. Miles (1954) at Wye in S.E. England reported two generations and a partial third and showed that egg-laying starts during the last two weeks of April. Hughes _et al_. (1959) and Coaker and Wright (1963) reported three generations a year in the Wellesbourne area, Warwickshire. Shaw (1965) in N.E. Scotland mentioned that egg-laying by _E. brassicae_ started in Mid-May, the main egg-laying period of the first generation was during June and that egg-laying was continued till the end of September or the beginning of October.

Effect of weather:

Weather conditions have a considerable effect on the behaviour and oviposition of the cabbage root fly and on the subsequent damage caused to crops. Investigations by Miles (1951, 1953 and 1954) showed that while warm and sunny weather encourages activity, feeding and egg laying, cold, wet and windy weather drives them to shelter in soil crevices or thick herbage. Brittain (1927) reported that enforced shelter during a long period of inclement weather results in the death of many through starvation. Swailes (1958) reported that weather conditions caused two conspicuous drops in the numbers of eggs laid by the cabbage root fly, the first when wind speeds averaged 38, 34 and 25 m.p.h. during three consecutive days, and the other when the weather was marked by cool conditions and 2·3 inches of precipitation. Read (1958b) reported that dry weather, resulting in drying of the surface soil, has reduced the number of maggots in a turnip crop, and suggested that eggs and young larvae died before gaining entry into the roots. Brittain (1927) mentioned that eggs placed on damp soil were more likely to hatch than those kept under dry conditions.

Diapause:

The cabbage root fly overwinters in diapause in the pupal stage. Hughes (1960) suggested that diapause is induced by the day-length at some stage of the larval development. Missonier (1964) mentioned that temperature induced diapause during the larval stage. Read (1965) concluded that the stimulus resulting in diapause must be triggered in the adult and then later activated in the pupal stage. He was able to rear the pest continuously by fluctuating the air temperature from 60 to 65°F. at night to between 75 and 80°F during the day. Coaker and Wright (1963) in Wellesbourne showed that diapause extends for 105-126 days at a constant temperature of 41°F. and terminates, in the field, at the end of January or the beginning of February and that a mean of 258·4 ± 22 day degrees above 42°F are required from the beginning of February for the emergence of the cabbage root fly adults in the field.

Chemicals used for the control of the cabbage root fly:

Aldrin, Dieldrin, B.H.C. and calomel were recommended by the Ministry of Agriculture for the control of the cabbage root fly in 1961 (Agricultural Chemicals Approval Scheme). In 1965 the use of aldrin and dieldrin formulations was limited by agreement under the Pesticides Safety Precautions Scheme. In 1966 the organophosphorus compound diazinon was added to the list of insecticides recommended for the control of the cabbage root fly, followed by chlorfenvinphos, phorate and thionazin in 1967. Coaker and Finch (1965 and 1966) obtained a high level of cabbage root fly control using diazinon, thionazin, azinphos-methyl and mecarbam as drenches.

The development of resistance to insecticides:

Coaker et al. (1963) reported a strain of root flies resistant to dieldrin at Great Rollright farm in the south of England and mentioned that plants treated at ten times the amount normally required to kill susceptible larvae were as severely damaged as the untreated ones and showed that diazinon was highly effective. The spread of the resistant strain was further studied by Coaker and Mowat (1965).

Howitt et al. (1955 and 1962) in U.S.A., Morris (1963), Read (1964 and 1965), Niemczyk (1965), Stewart and McKinlay (1965) in several areas of Canada reported that strains of the cabbage root fly hightly resistant to chlorinated hydrocarbon and certain organo-phosphorous insecticides have developed. Harris et al. (1962) mentioned that resistance has developed in areas where broadcast applications of insecticides have been applied to the soil over several consecutive years and suggested that other methods than broadcasting should be used.

EXPERIMENTAL PROCEDURE

Predation by Carabidae and Staphylinidae on the egg stage was by far the most important biological controlling factor. The time during which each species of beetle occurred in the field and their relative abundance during the egg-laying period of the root fly, were studied. The reduction in population of each species of beetle which followed the application of diazinon or chlorfenvinphos granules was investigated. The insecticides were applied around the plants either on or under the surface of the soil. The effect of these treatments was also investigated by laboratory experiments on the Carabidae.

Predation by beetles on the egg stage of the cabbage root fly was studied in the field in each insecticidal treatment and the control, using individual plant barriers to keep the area around certain plants as free as possible from Carabidae and Staphylinidae. Eggs were sampled from plants with and without barriers throughout the egg laying periods of the fly.

The control of the root fly by the two insecticides and the consequent effect on the crop were recorded. Diazinon was also used for the control of the pest on cauliflower, brussels sprouts and turnips in four other sites in addition to the main experimental plot at Seafield. General observations on the cabbage root fly and the damage it causes to crops were made.

The effect of temperature on the emergence of the adult flies from the overwintering pupae and the effect of adverse weather conditions on egg laying by the flies were investigated.

METHODS AND MATERIALS

Site:

The investigations were carried out under field conditions in the experimental plots of Edinburgh University at Seafield "field number 14". The experimental area is 560 ft. above sea level. The soil is loam with pH 6·3. The north-western side of the experimental field is sheltered by a strip of woodland. Brassica crops are frequently grown in the area mainly for animal consumption. In field No.14 no cruciferous crops were grown in 1960 and 1961. Kale was grown in 1962, 1963 and swedes in 1964. No insecticides were used in the field before 1964 when thionazin, phorate, diazinon and chlordane were applied to the swede crop.

1965 trial:

The crop was cabbage variety "January King" and two treatments of 5% diazinon granules at the rate of 0·8 grammes per plant were applied.

a) Surface treatment (application of the granules around the base of each plant after planting).

b) Sub-surface treatment (the insecticide was stirred into an area of about 10 sq. inches of surface soil, and the plant was planted firmly in the centre of this area). The insecticide was applied with a small measure made to hold the amount of granules required for one plant. The two treatments and a control were replicated three times in a randomized block design, each plot contained 180 plants (12 x 15) spaced at 2 ft. each way (Figure 1A). The plots were surrounded by two rows of untreated plants.

The soil was cultivated, the diazinon in the sub-surface treatment was applied and the cabbages were transplanted on April 30 and May 1, 1965. The insecticide for the surface treatment was applied on May 5. Pigeons caused some damage by feeding on the young plants. Weeding was carried out on two occasions during the season. On June 10 and 11, a tractor was used to weed between the plants. This was followed by pulling out the weeds near the plants by hand. The second weeding was carried out in the last week of July using hand hoes. This method was thought to be better as the tractor had damaged some of the plants. No chemical weeding was used as it might have affected the insects present in the plots.

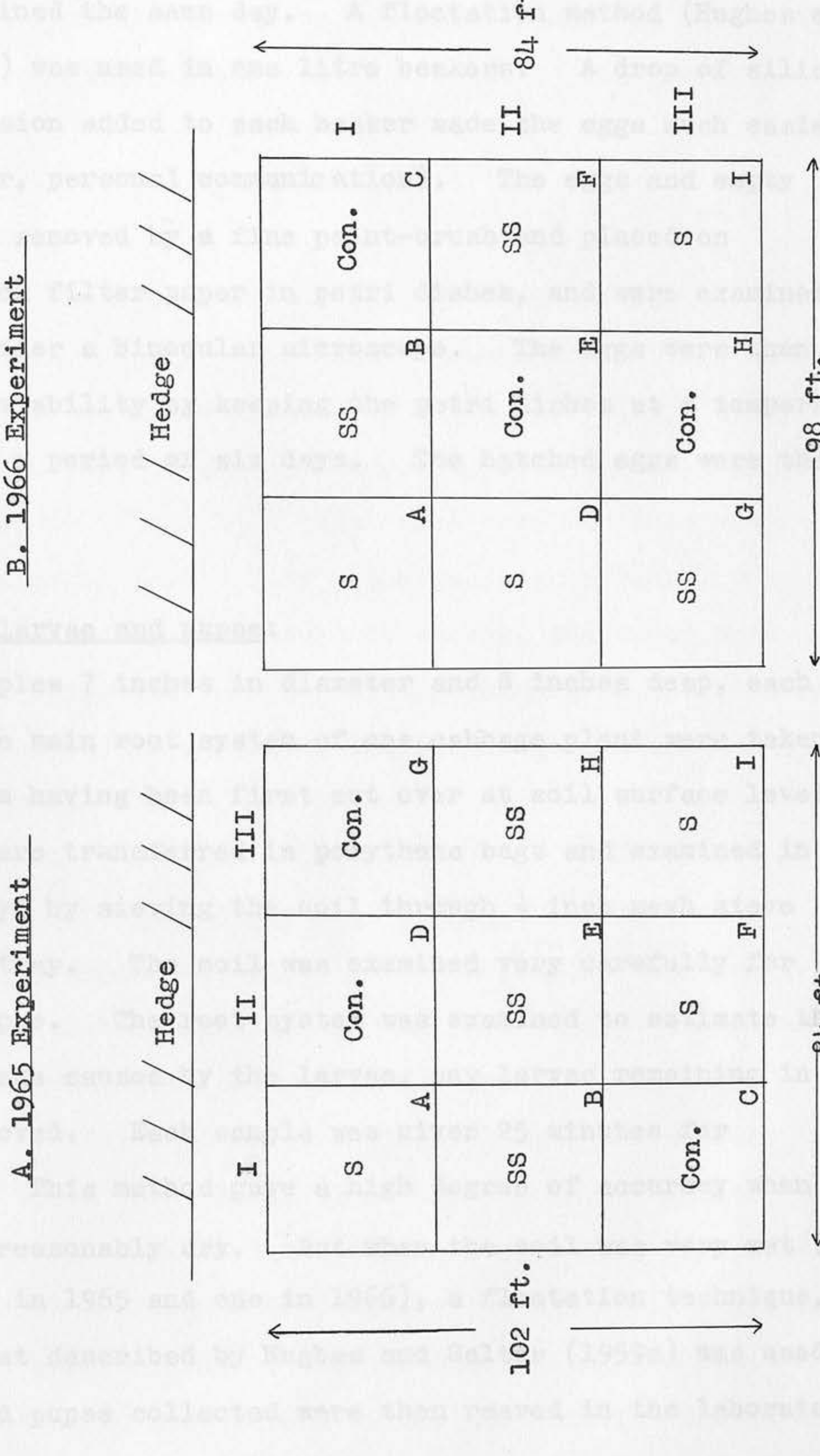
1966 trial:

The same treatments of 1965 were repeated using 10% chlorfenvinphos granules at 0·5 grammes per plant. The soil was ploughed, rotavated, rolled three times and cabbages, variety "Paragan" were transplanted from May 9 to 11. The blocks were arranged to be parallel to the hedge (Figure 1B). Each plot included 208 plants (16 x 13). The plots were separated by 4 ft. of bare soil. Weeding was carried out by hand hoeing in the second week of June and during the third week of July.

Sampling for eggs:

The plants around which samples were taken were selected at random. The soil within a 5 c.m. radius of the cabbage stem, and to a depth of 2 c.m. was carefully removed with a tablespoon.

Fig. 1


A. 1965 Experiment
Hedge
I
II
III
S
A
Con.
D
Con.
G
SS
B
SS
E
SS
H
Con.
C
S
F
S
I
102 ft.
84 ft.
B. 1966 Experiment
Hedge
I
S
A
SS
B
Con.
C
II
S
D
Con.
E
SS
F
III
SS
G
Con.
H
S
I
84 ft.
98 ft.

The samples were taken to the laboratory in plastic containers, and were examined the same day. A floatation method (Hughes and Salter, 1959a) was used in one litre beakers. A drop of silicone antifoam emulsion added to each beaker made the eggs much easier to see (Coaker, personal communication). The eggs and empty chorions were removed by a fine paint-brush and placed on moistened black filter paper in petri dishes, and were examined and counted under a binocular microscope. The eggs were then examined for viability by keeping the petri dishes at a temperature near 20°C for a period of six days. The hatched eggs were then recorded.

Sampling for larvae and pupae:

Soil samples 7 inches in diameter and 8 inches deep, each containing the main root system of one cabbage plant were taken, the plant stem having been first cut over at soil surface level. The samples were transferred in polythene bags and examined in the laboratory, by sieving the soil through ½ inch mesh sieve into a large tray. The soil was examined very carefully for larvae and pupae. The root system was examined to estimate the degree of damage caused by the larvae, any larvae remaining in the root were removed. Each sample was given 25 minutes for examination. This method gave a high degree of accuracy when the soil was reasonably dry. But when the soil was very wet (on two occasions in 1965 and one in 1966), a floatation technique, similar to that described by Hughes and Salter (1959a) was used. The larvae and pupae collected were then reared in the laboratory to determine the percentage of parasitism. The damage caused by the cabbage root fly larvae to the plant roots was recorded on the basis: 0 none; 1 slight; 2 medium; 3 considerable; 4 severe.

Adult emergence:

The time of emergence of the cabbage root fly adults was determined during the first and second generations of the cabbage root fly in 1966. Six emergence cages (Turnock, 1957) were placed on the surface of the soil where turnips had been harvested in September, 1965 (Plate 1). The cages were examined every day during the emergence period, and the results recorded. When the first generation adults had ceased to emerge, the cages were transferred to cover two infested cabbage plants in each control plot. The times of emergence of the second generation adults were thus recorded.

Sampling for Carabid and Staphylinid beetles:

A pitfall trapping technique (Mitchell, 1963) was used to determine the population changes of the Carabid and Staphylinid beetles. One-pound jam jars served as traps. These were sunk into the soil so that their rims were level with the surface. Three pitfall traps were placed at a distance of two inches from the stem of each alternate plant, in the centre row of each plot. The contents of the traps were carefully emptied every three days, usually in the morning, into plastic containers. The beetles captured in each trap were sorted on the spot and the number of each species was recorded. They were then returned once more to

Plate 1. Adults emergence cages.

Plate 2. A pitfall trap

the plot. The jam-jars were cleaned with a dry cloth and the surrounding soil smoothed over especially after rainy or very dry weather. The traps were covered with chicken-wire resting above the jars to protect the trapped beetles from predation by birds (Coaker, 1965). On several occasions during the 1965 experiment, heavy rain was found to fill the traps very rapidly, whereas moderate rain made it easy for the smaller beetles to climb out of the traps, especially the smaller Staphylinidae, i.e. Atheta spp. This difficulty was reduced to a large extent in the 1966 experiment by adding a transparent polythene sheet, attached to the chicken-wire (Plate 2), above each jar. After heavy rain no readings were taken and all the jars were washed and dried.

Another improvement was introduced in the pit-traps. A small quantity of moist soil was added to each jar. This procedure kept the beetles alive in the traps during hot and dry weather. It was also noted that fewer beetles attempted to climb up the sides of the jars, in these circumstances, it was observed that more beetles climbed the sides of the jars devoid of soil. It was also felt that this procedure might have reduced the amount of predation inside the traps by the larger Carabidae.

Barriers to study the effect of predation on:

(a) The egg stage of the cabbage root fly

Barriers were used round individual plants to keep the areas around the stems as free as possible from Carabid and Staphylinid beetles. The barriers enclosed an area of 23 square inches and were made from aluminium 0·024 inch thick. Strips

20 by 4 inches were cut and the upper edges were bent outwards to form ½ inch wide lips. The corners of the out-turned lips were filled with pieces of the same metal, fixed by Tico-adhesive A/GE. The outersides of the barriers were coated with a silicone fluid film (F 111/100). This treatment made it more difficult for the beetles to climb up the barrier, and kept the walls cleaner.

Each barrier was sunk into the soil around the plant and the soil surrounding the barrier was removed to form a three inch wide, three and a half inch deep channel (Plate 3). This allowed the beetles to fall out of the area enclosed by the barrier into the channel, and prevented beetles from entering the same area.

Four sets of barriers were sunk into the soil around individual plants chosen at random. Each set contained 9 barriers (one per plot) in 1965, and 18 barriers (two per plot) in 1966. Each set was placed at three day intervals until there were 36 barriers (four per plot) in 1965, and 72 barriers (eight per plot) in 1966. Egg samples were taken from the plants within the barriers 12 days after positioning them, and the barriers were then transferred to a new set of plants. Thus there was a set of samples taken every three days. At the same time an equal number of egg samples was taken from around plants without barriers selected at random.

The Carabid and Staphylinid beetles found in the soil sampled for root fly eggs, from around cabbage plants with and without barriers were recorded throughout the season. Only 7 and 9 of the smaller Staphylinidae, Atheta spp., were found in the samples taken from the barrier-protected plants in 1965 and 1966

Plate 3. A plant barrier

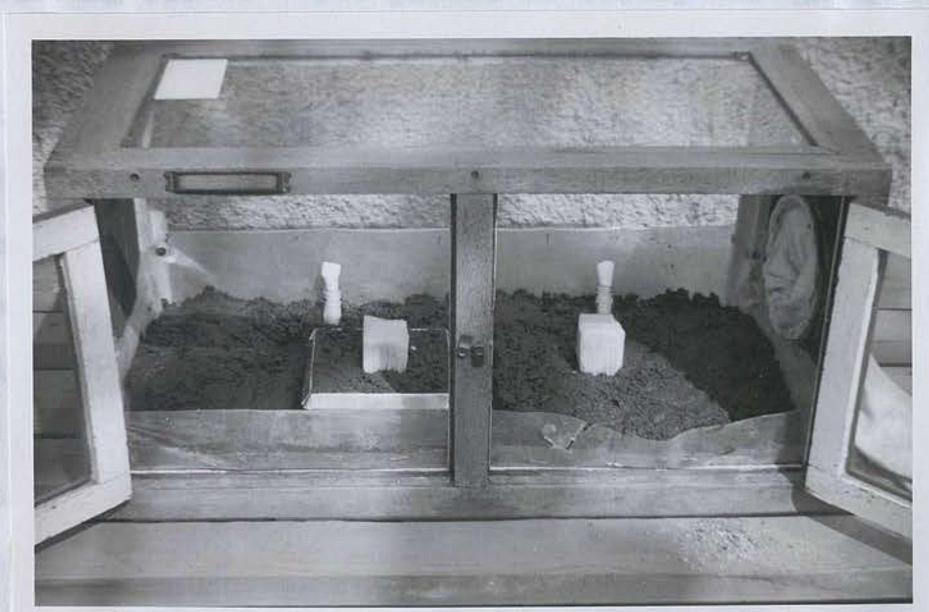


Plate 4. A barrier inside a fly rearing cage.

respectively, compared with 71 beetles (44 Atheta spp., 11 O. rugosus, 12 T. obtusus and 4 other Carabidae) in 1965 and 70 beetles (48 Atheta spp., 13 O. rugosus, 4 T. obtusus and 5 other Carabidae) in 1966 were found in the egg samples taken from plants without barriers. Individual plant barriers were used by Coaker (1965). Each barrier surrounded a plant above the soil enclosing an area 1 ft. square, and had a 1 inch overhanging lip, with a strip of plastic sheeting stuck to the underside of it. A pitfall trap was embedded next to the plant within the barrier, and in it were trapped a few Carabid beetles. The number of Staphylinids was unaffected by the barrier treatment. These barriers, however, were also found to deter ovipositing flies, and there were fewer eggs found around plants surrounded by the barriers than around unprotected plants. A laboratory experiment was carried out to test whether the barriers used in the present study had any deterrent effect on the ovipositing flies. Two pieces of turnip were placed into the soil in an adult rearing cage; one piece had the barrier treatment (Plate 4). Adult flies were released in the cage and were provided with a 10% sugar solution and water. Egg samples were taken at an interval of seven days when fresh pieces of turnip were substituted. The numbers of eggs sampled from the turnip with the barrier treatment were 127, 170, 85 and 67, compared with 98, 180, 94 and 34 from the turnip without the barrier treatment. This result shows that the barriers had no deterrent effect on the ovipositing flies.

(b) The larvae and pupae:

The effect of predation on the larvae and pupae of the first and second generations of the cabbage root fly was examined in 1966 by placing barriers around three plants selected at random in each treated plot, and six plants in each control plot. These barriers were cleaned and dried occasionally and the channels surrounding them were cleared especially after rain. The barriers were kept in position from the 24th May till the 12th July when the egg-laying of the root fly first generation adults was reduced to a minimum. Soil and plant samples were taken and examined for larvae and pupae by the previously described method. The barriers were cleaned and placed around a new set of plants on the following day. These plants were chosen at random, those which were very large or badly stunted being rejected. Soil and plant samples were taken on the 4th September. A similar number of samples were taken from randomly selected plants without barriers on each occasion.

RESULTS

I. The effect of insecticides on Carabid and Staphylinid predators when used as a control for cabbage root fly:

In order to utilize the predatory Carabids and Staphylinids in controlling the cabbage root fly it is essential to know the effects of insecticides on these natural enemies of the pest. The kind of insecticide used, the time and method of its application might have different effects on both the pest and its natural enemies. In the present investigation two organo-phosphorus insecticides were used in the field experiments. Diazinon was used in 1965 and chlorfenvinphos in the following year.

A - Diazinon:

Diazinon or O, O-Diethyl O-(2-isopropyl-4-methyl-6-pyrimidinyl) phosphorothioate or sometimes referred to as G-24480 was first recommended in Great Britain for the control of the cabbage root fly as a post-planting drench. Experimental results are summarised in the March 1965 supplement of Plant Pathology 14(1) Coaker et al. (1963 and 1965) showed that diazinon is a useful alternative to aldrin and dieldrin for the control of the pest when applied as a 0·03-0·05 per cent a.i. drench treatment. The granular formulation of diazinon has been demonstrated by Hartley and Geering (1965) to provide satisfactory control of the pest. Coaker and Finch (1966) obtained 80 per cent reduction in the root damage to a cauliflower crop by the application of diazinon granules containing 2 lb. a.i. per acre in a 3 in. wide and 1-2 in. deep band. The diazinon is a short lived insecticide. Getzin and Rosefield (1966) showed that under laboratory conditions the original application of C^{14}-labelled diazinon was lost in 2 to 4 weeks and less than 8% remained after 20 weeks. In the field he reported that a rapid loss of toxicant during the first 8 weeks was followed by a much slower decline.

As the diazinon loses its effectiveness eight to twelve weeks after application, it is only expected to give protection against the first generation of the cabbage root fly. After this period the plants, however, should be well enough established to withstand the following attacks of the pest. Using such an insecticide will expose the natural enemies to the toxic effect only for a limited time, after which their population may increase freely.

In the present study the diazinon was used in the 5 per cent granular form. The plots were set up as previously described and the granules were applied at the rate of 0·8 grammes per plant. The pitfall traps were placed in the field on May 18 and were examined every 3 days till October 23, except after heavy rain when the traps were unreliable for sampling.

The effect of the surface and the sub-surface diazinon treatments on the number of Carabidae and Staphylinidae captured in the pitfall traps was as follows:

1- On Carabidae:

Over a period of approximately 11 weeks from the application of the insecticide there were consistently more Carabid beetles trapped in the control plots than in both the two insecticidal treatments, and also consistently more in the sub-surface treatment than in the surface treatment (Fig. 2). In order to find out the difference between the number of beetles occurring in each of the two treatments and the control at consecutive periods during the season, the number of beetles trapped per plot over 9-day periods was taken and analysed separately. The mean number of Carabidae captured per plot during each of these periods throughout the season are shown in Table 1, and the difference between the mean catch in each of the two treatments and the control are shown in Table 2. A consistent significant difference is apparent between each of the two treatments compared with the control, throughout the period from May 18 till July 21. The difference between the sub-surface treatment and the control is shown to be of less significance compared with the difference between the surface treatment and the control.

The sub-surface treatment seems to have lost its toxic effect on the adult Carabidae earlier than the surface treatment. This can be seen from the decrease in the significant difference between the sub-surface treatment and the control towards the end of June and beginning of July. The same can be noticed also from the increased significance between the surface and the sub-surface treatments during that time. This observation can also be seen in Fig. 2, when the number of Carabids in the sub-surface treatment started to rise from the end of June and reached a level near the control, while the number of Carabidae captured in the surface treatment was still low.

The mean number of Carabidae trapped during the period from

Fig. 2 Carabidae

1965

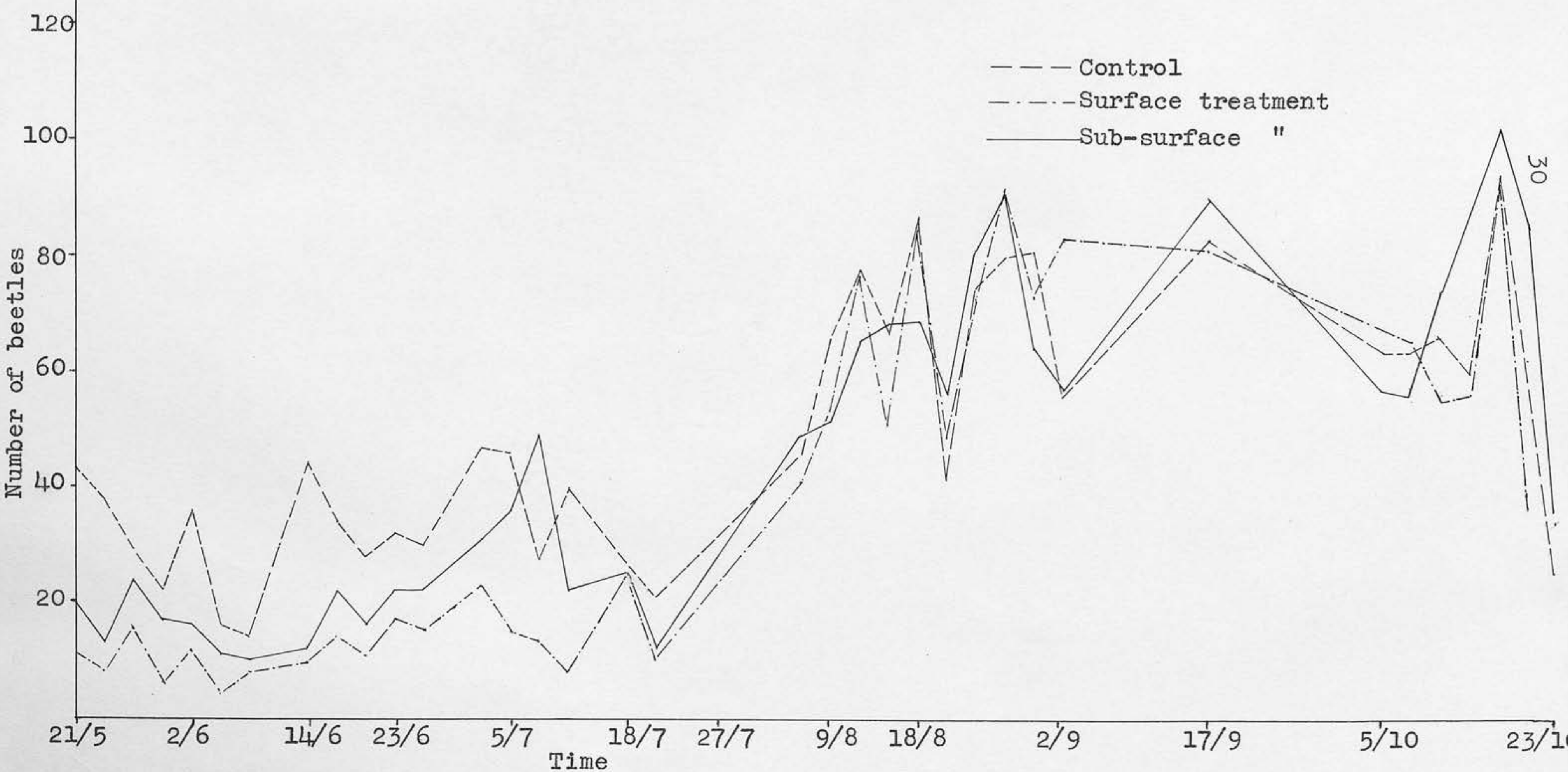


TABLE 1

Mean number of Carabidae captured per plot in the two diazinon treatments and the control every 9 days throughout the 1965 experiment

Period	Control	Surface	Sub-surface	L.S.D.	Treat. variance ratio[c]
18/5 - 27/5	36·7	11·7	19·0	a 16·5 b 27·4	9·3*
27/5 - 5/6	24·7	7·3	14·6	a 8·2 b 13·6	17·3*
5/6 - 8/6 11/6 - 17/6	30·7	11·0	14·6	a 15·2 b 25·1	7·3*
17/6 - 26/6	30·0	14·3	20·0	a 3·1 b 5·2	97·3**
30/6 - 8/7	40·0	16·0	38·6	a 8·5 b 14·0	39·1**
8/7 - 11/7 15/7 - 21/7	29·3	14·3	19·0	a 8·7 b 14·4	11·9*
TOTAL	191·4	74·6	125·8	a 36·2 b 60·0	40·2**
9/8 - 18/8	76·3	72·0	67·6	n.s.	0·3
18/8 - 27/8	65·7	71·0	76·0	n.s.	0·4
27/8 - 2/9 14/9 - 17/9	73·3	79·0	70·3	n.s.	0·4
5/10 - 14/10	63·3	58·7	67·0	n.s.	< 1
14/10 - 23/10	60·3	61·7	74·6	n.s.	< 1
TOTAL	338·9	342·4	355·5	n.s.	0·2

a L.S.D. between treatments means (P = 0·05).
b " " " " (P = 0·01).
c The variance ratio (P = 0·05) is 6·9 and (P = 0·01) is 18.
* significant (P = 0·05)
** significant (P = 0·01)

TABLE 2

The difference between the mean number of Carabidae captured per plot in the two treatments and the control every 9 days from May 18 till July 21

Period	Con. - Surface	Con. - Sub. S.	Sub. S. - Surface	L.S.D.
18/5 - 27/5	25·0*	17·6*	7·4	a 16·5 b 27·4
27/5 - 5/6	17·3**	10·0*	7·3	a 8·2 b 13·6
5/6 - 8/6 11/6 - 17/6	19·6*	16·0*	3·6	a 15·2 b 25·1
17/6 - 26/6	10·0**	15·7**	5·7**	a 3·1 b 5·2
30/6 - 8/7	24·0**	1·4	22·6**	a 8·5 b 14·0
8/7 - 11/7 15/7 - 21/7	15·0**	10·3*	4·7	a 8·7 b 14·4
18/5 - 21/7	116·7**	65·3**	51·4*	a 36·2 b 60·0

a L.S.D. between treatments means (P = 0·05)

b " " " " (P = 0·01)

* significant (P = 0·05)

** significant (P = 0·01)

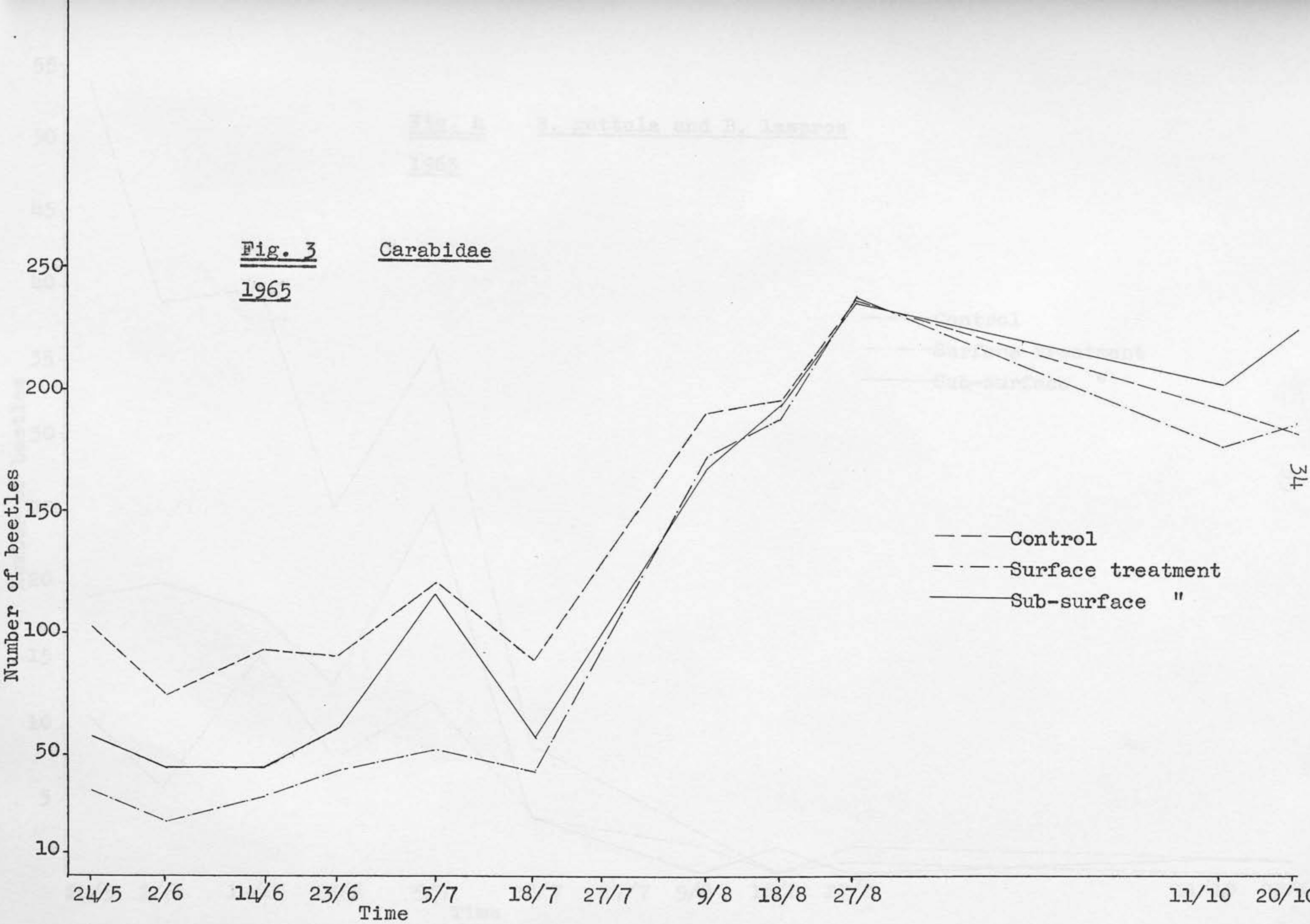
May 18 to July 21 (Table 2) was significantly greater (P = 0·01) in the control treatment than in the two insecticidal treatments, and the mean number of Carabidae captured in the sub-surface treatment was significantly greater (P = 0·05) compared with that of the surface treatment.

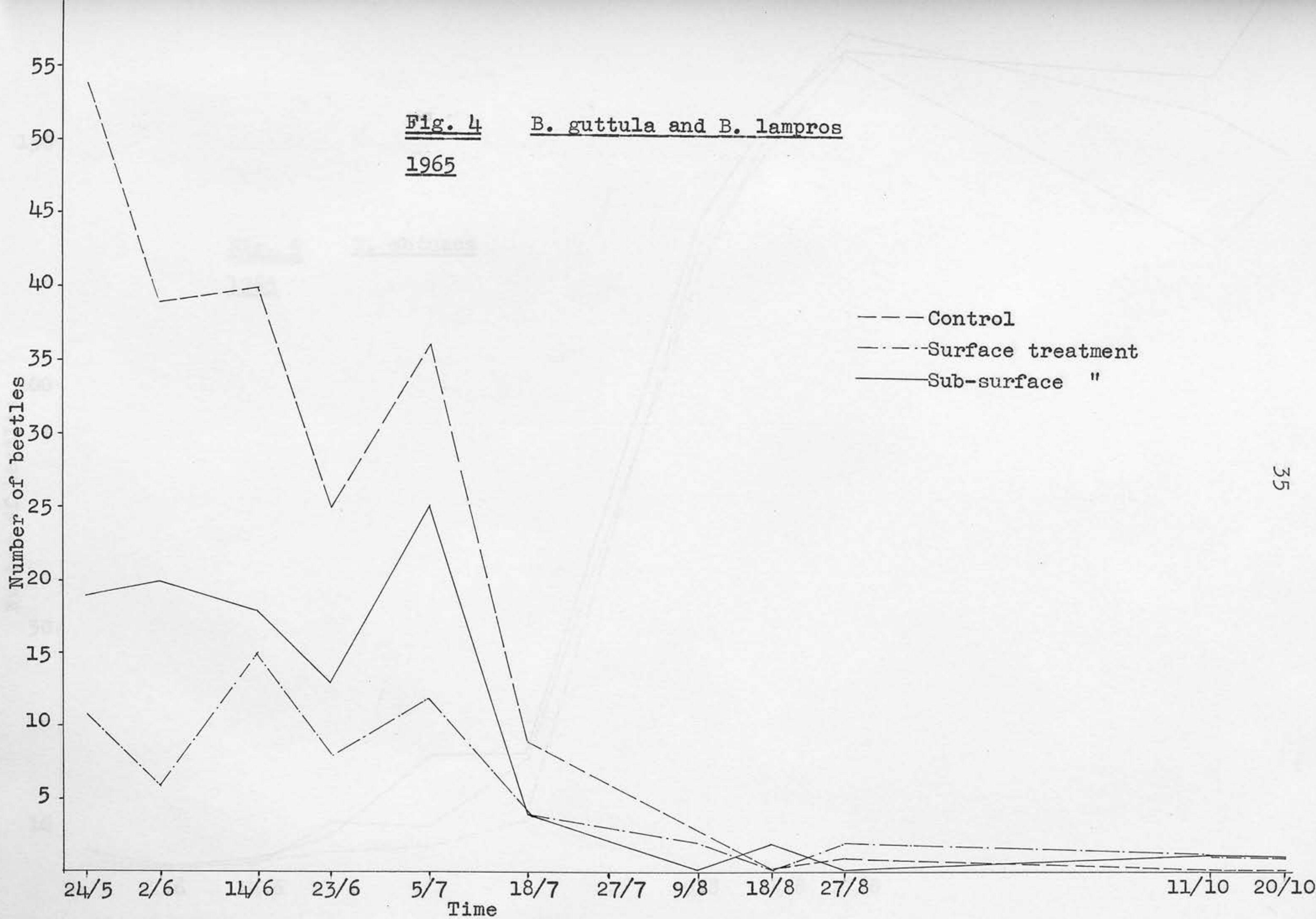
The last week of July and the first week of August were periods of heavy rainfall, after which the insecticide had more or less lost its effectiveness. During this time it was not possible to operate the pitfall traps as they became rapidly filled with water. After this period there was no difference between the number of beetles in any of the treatments and the control (Fig. 2, Table 1). The number of Carabidae trapped over 9-day periods throughout the season is shown graphically, for the Carabidae family collectively (Fig. 3), and for each Carabid species or group of species separately (Fig. 4 to 9).

As it was difficult to separate the two species Bembidion guttula F. and B. lampros in the field, they were recorded as one group. Samples were brought into the laboratory on four occasions. These indicated that about 89 per cent of the beetles included in this group were B. guttula. The population of B. guttula and B. lampros occurred mainly in the first part of the season, when the diazinon treatments were most effective. Therefore they suffered more losses than the other Carabid species. It is shown in Fig.4 that the number of beetles belonging to these two species was reduced to a large extent especially in the surface treatment compared with the control. The mean number captured in the control, the sub-surface and the surface treatments per plot was 67, 33 and 18 respectively. The difference

Fig. 3 Carabidae

1965





<u>Fig. 4</u> <u>B. guttula and B. lampros</u>

<u>1965</u>

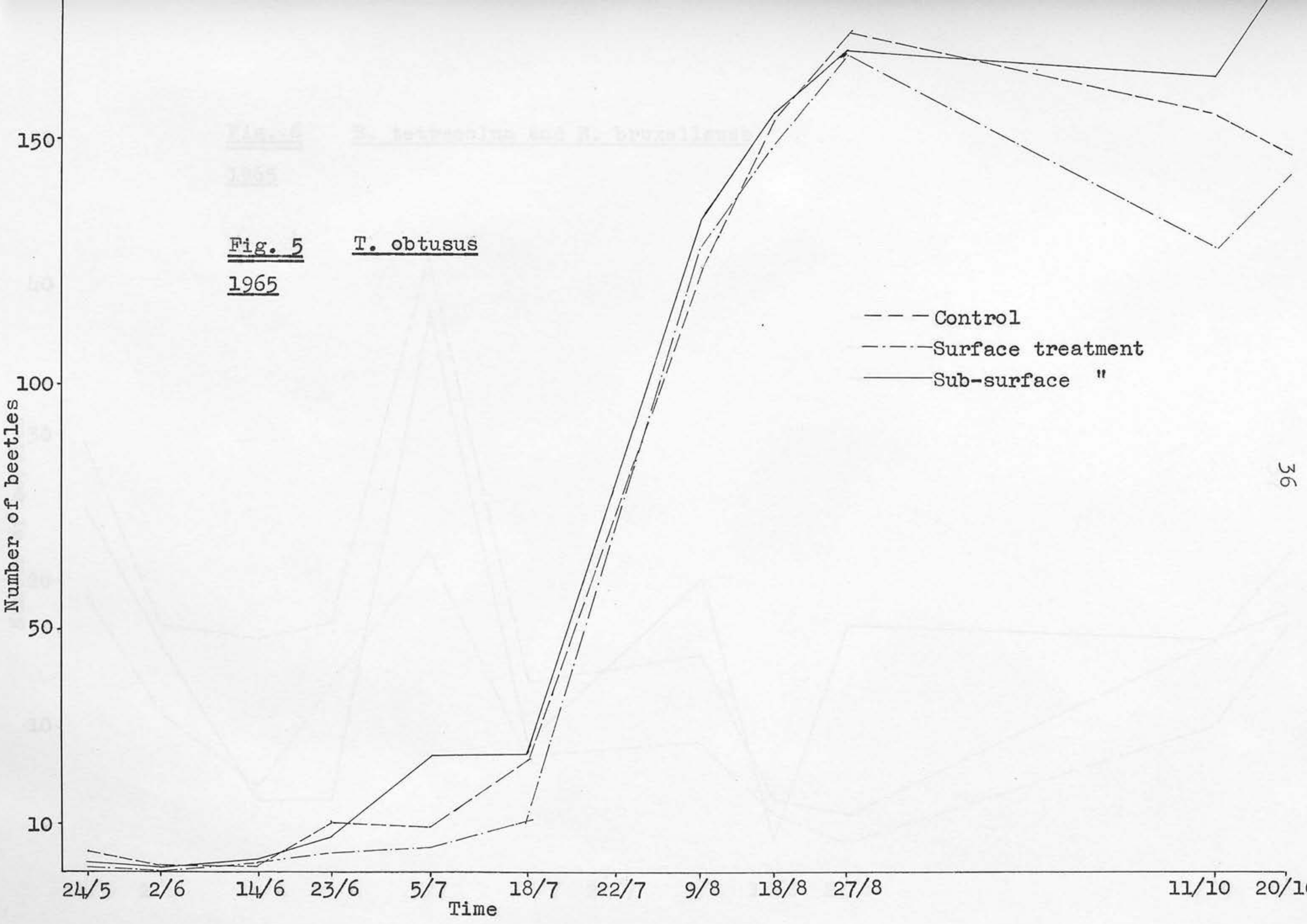


Fig. 5 T. obtusus
1965

Fig. 6 **B. tetracolum and B. bruxellense**

1965

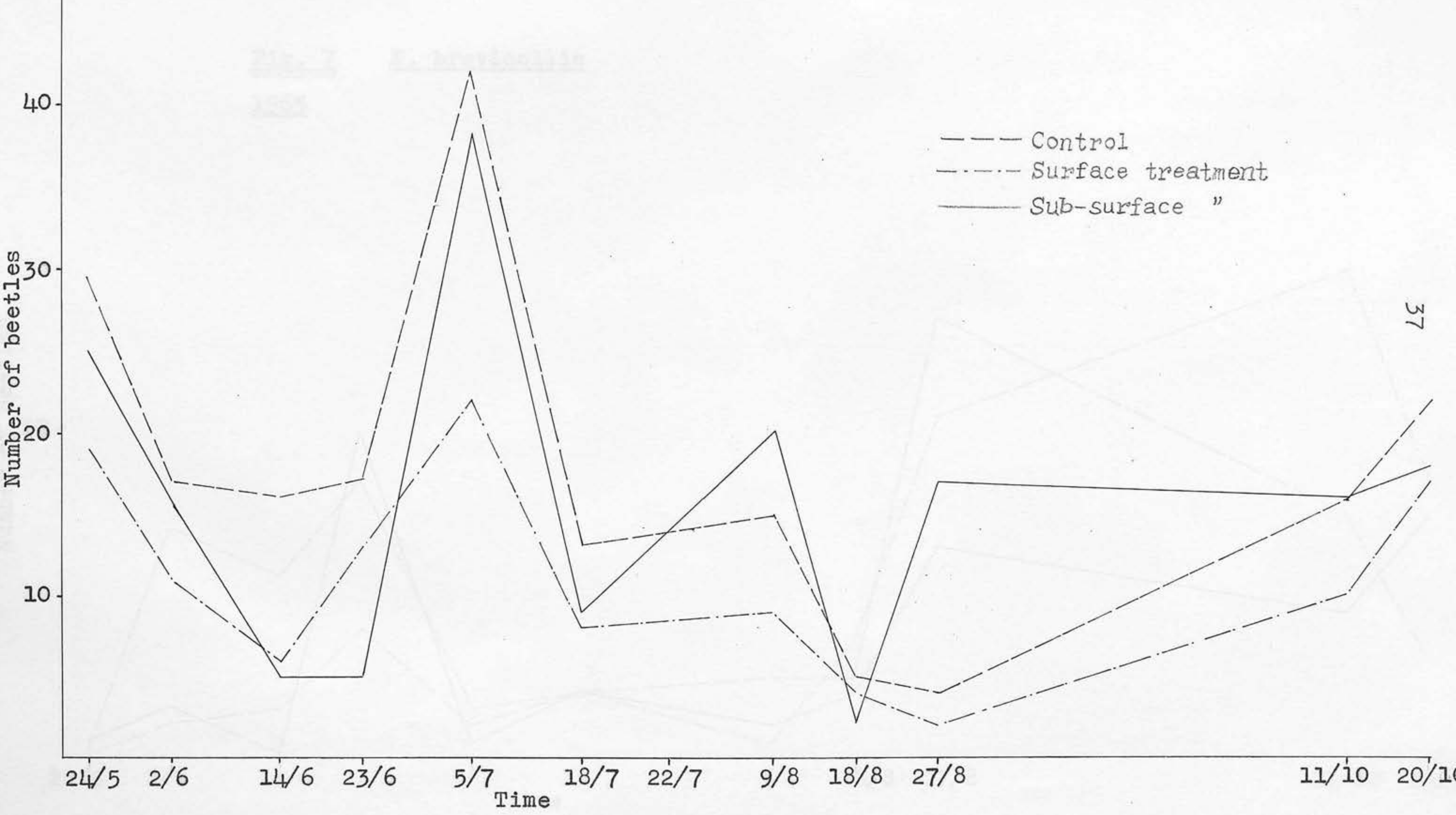
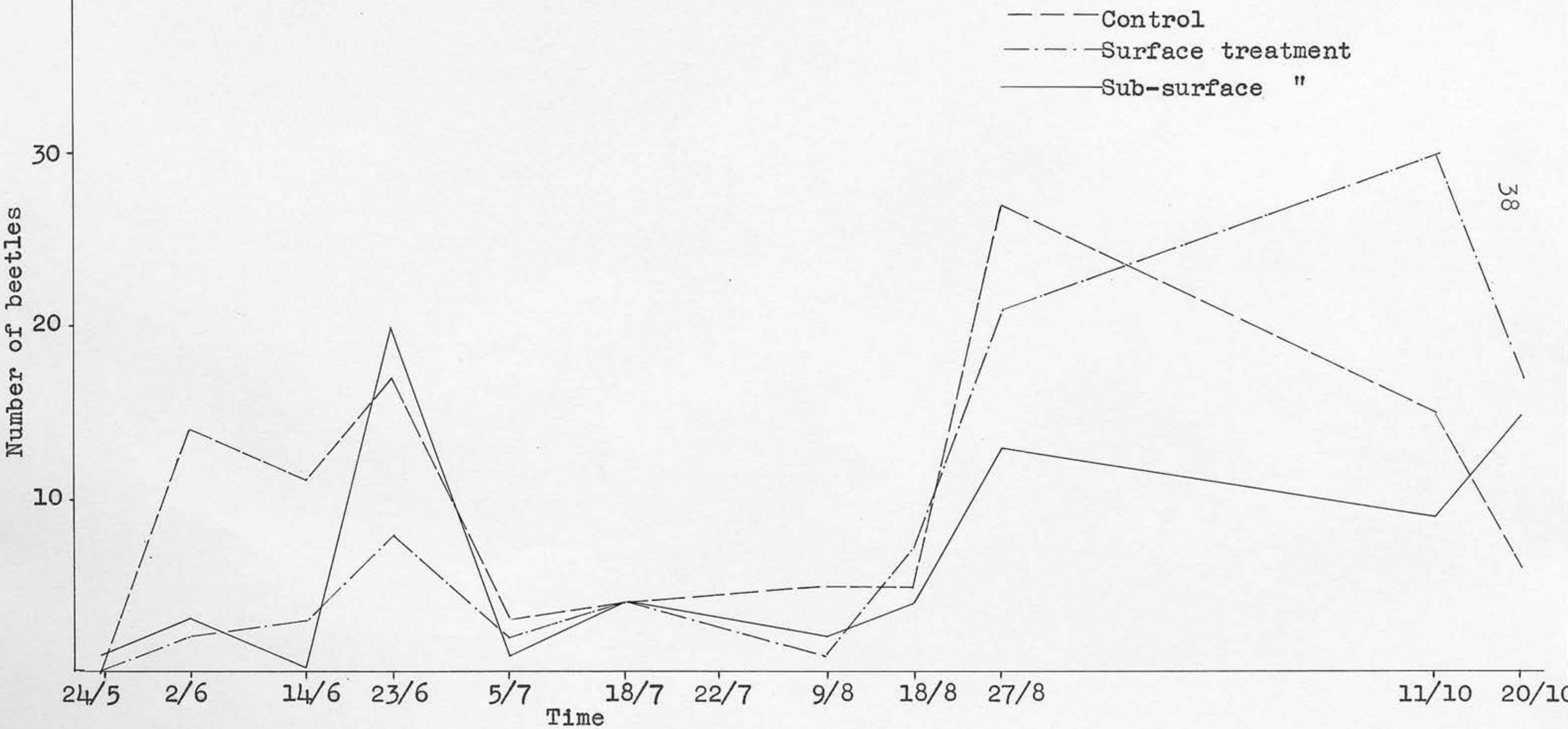


Fig. 7 N. brevicollis

1965



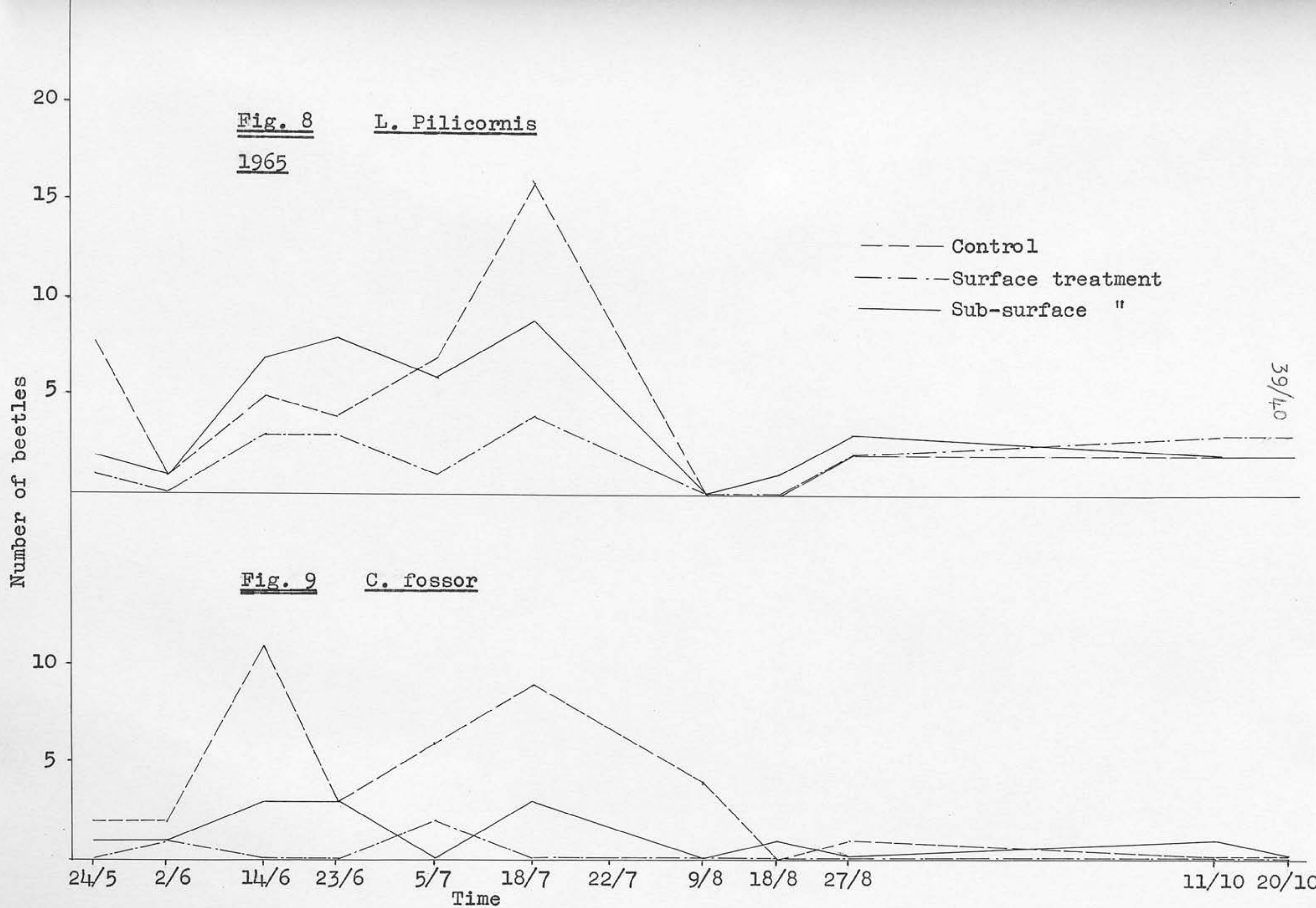


Fig. 8 L. Pilicornis
1965

Fig. 9 C. fossor

between these means is not statistically significant, but the variance ratio is very near to the 5% level of significance. The population of these 2 species was reduced gradually during the beginning of July, and very few individuals were trapped thereafter.

On the other hand, only a few T. obtusus occurred during the earlier part of the season, when the insecticide was effective. The main bulk of the population of this species occurred during August, September and October (Fig. 5), and therefore the effect of the diazinon treatments on this species was negligible.

Bembidion tetracolum Say, B. bruxellense Wesmael; Nebria brevicollis F.; Loricera pilicornis F.; and Clivina fossor (Linnaeus) occurred in varying numbers during the season. The time each of these beetles occurred in the field and the effect of the two diazinon treatments on each, can be seen from figures 6, 7, 8 and 9 respectively. It can be noted that the number of beetles captured in the surface treatment during the period when the insecticide was effective, was almost always below those from the control and the sub-surface treatments, and the number captured in the control almost always higher than in the sub-surface treatment.

Other Carabids were captured in smaller numbers in the field mainly Amara apricaria (Paykull), A. familiaris (Duftschmid), A. bifrons (Gyllenhal), A. plebeja (Gyllenhal), A. eurynota (Panzer), Pterostichus madidus (Fabricius), P. strenuus (Panzer), Patrobus assimilis Chaudoir, Calathus melanocephalus L., C. fuscipes Goez, Notiophilus biguttatus F. and N. substriatus Waterhouse (Table 3).

TABLE 3

Total number of each group of Carabidae captured in the surface, the sub-surface diazinon treatments and the control during the 1965 experiment

	May 18 till July 21			Aug. 9 till Oct. 23		
	Con.	S.	S.S.	Con.	S.	S.S.
B. guttula, B. lampros	203	56	99	4	7	4
T. obtusus	48	23	60	870	829	914
B. tetracolum, B. bruxellense	134	79	98	62	43	77
N. brevicollis	49	19	29	75	91	62
Amara spp.	8	14	10	23	23	14
L. pilicornis	41	12	33	7	8	11
Pterostichus spp.	10	11	9	16	20	25
C. fossor	33	3	11	5	0	2
P. assimilis	1	0	3	10	11	7
Calathus spp.	0	1	0	4	3	1
Notiophilus spp.	3	2	0	3	6	4
Other species	18	4	17	9	17	22
TOTAL	548	224	369	1088	1059	1143

2- On Staphylinidae

The Staphylinidae were affected differently from the Carabidae by the two diazinon treatments. It is shown in Fig. 10 that the number of Staphylinidae captured over 9-day periods, from May 18 till July 21, in the surface treatment was consistently lower than both the control and the sub-surface treatment. There was no significant difference between the mean number of Staphylinidae captured during this period in the sub-surface treatment compared with that of the untreated control plots (Tables 4 and 5), while the number captured in the surface treatment was significantly lower (P = 0·05) than that of both the control and the sub-surface treatment.

These results indicate that the Staphylinidae while being susceptible to the diazinon surface treatment appear, however, to withstand the sub-surface treatment very well.

The smaller Staphylinid beetles mainly of the species Atheta gregaria Er., A. sodalis Er. and A. xanthopus (Thomson) were captured in large numbers during the first part of the season, when the cabbage root fly generation was present in the field. The total catch of this group of beetles constituted 67 per cent of the total Staphylinidae captured throughout the season. The mean number of beetles belonging to this group captured per plot during the period from May 18 till July 7 in the control, the sub-surface and the surface treatments were 215, 195 and 110[1] respectively. The catch in the surface treatment was significantly lower (P = 0·05) compared with both the control and the sub-surface treatments. The difference between the surface treatment and the control was very near to the significance at 1% level; while the difference between the sub-surface treatment and the control was non-significant. This result shows that the mortality of this group of beetles was considerably reduced by the application of the diazinon granules under the surface of the soil compared with the application on the surface of the soil (Fig.11).

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1. L.S.D. between the means (P = 0·05) is 64·9 and (P = 0·01) is 108·5.

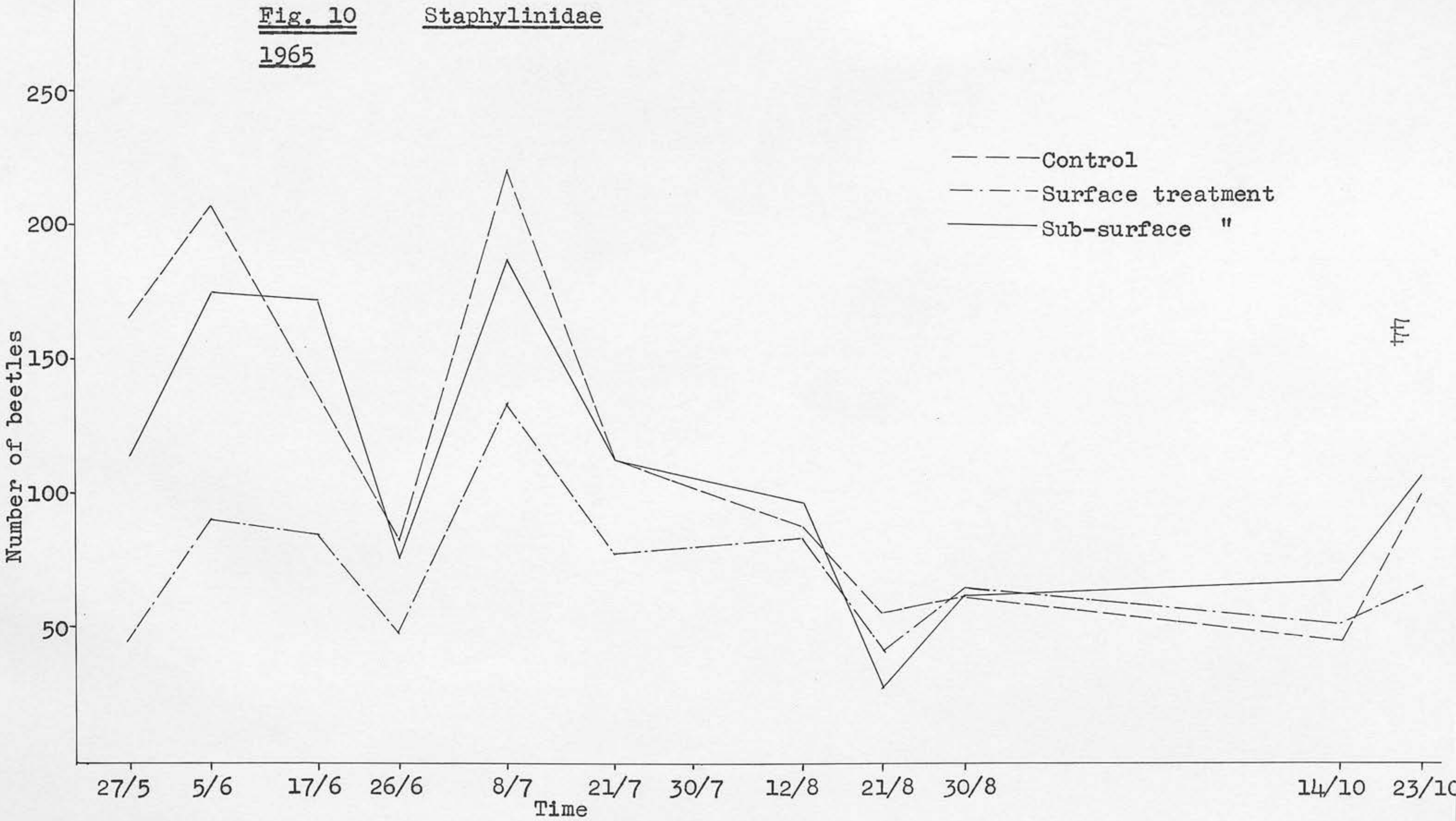

Fig. 10 Staphylinidae
1965
Control
Surface treatment
Sub-surface "
250
200
150
100
50
Number of beetles
27/5
5/6
17/6
26/6
8/7
21/7
30/7
12/8
21/8
30/8
14/10
23/10
Time

TABLE 4

Mean number of Staphylinidae captured per plot in the two diazinon treatments and the control every 9 days throughout the 1965 experiment

Period	Control	Surface	Sub-surface	L.S.D.	Treat. variance ratio[c]
18/5 - 27/5	55·7	15·7	38·3	a 24·4 b 40·5	10·3*
27/5 - 5/6	69·3	30·3	58·7	n.s.	5·3
5/6 - 8/6 11/6 - 17/6	44·3	30·0	57·7	a 10·0 b 16·6	27·8**
17/6 - 26/6	27·7	16·3	25·7	n.s.	2·4
30/6 - 8/7	73·7	45·0	62·2	n.s.	2·9
8/7 - 11/7 15/7 - 21/7	37·7	26·3	37·7	n.s.	1·0
TOTAL	308·4	163·6	280·4	a 96·5 b160·1	9·7*
9/8 - 18/8	19·7	18·3	15·3	n.s.	< 1
18/8 - 27/8	21·3	20·3	17·7	n.s.	< 1
27/8 - 2/9 14/9 - 17/9	19·7	15·3	15·7	n.s.	< 1
5/10 - 14/10	15·3	19·7	23·0	n.s.	< 1
14/10 - 23/10	33·7	22·3	36·3	n.s.	< 1
TOTAL	109·7	95·9	108·0	n.s.	< 1

a L.S.D. between treatments means (P = 0·05)

b " " " " (P = 0·01)

c The variance ratio (P = 0·05) is 6·9 and (P = 0·01) is 18.

* significant (P = 0·05)

** significant (P = 0·01)

TABLE 5

The difference between the mean number of Staphylinidae captured per plot in the two treatments and the control every 9 days from May 18 till July 21

Period	Con. - Surface	Con. - Sub-S.	Sub. S.- Surface	L.S.D.
18/5 - 27/5	40·0*	17·3	22·7	a 24·4 b 40·5
27/5 - 5/6	39·0	10·7	28·3	n.s.
5/6 - 8/6 11/6 - 17/6	14·3*	-13·3	27·7**	a 10·0 b 16·6
17/6 - 26/6	11·3	2·0	9·3	n.s.
30/6 - 8/7	28·7	11·3	17·3	n.s.
8/7 - 11/7 15/7 - 21/7	11·3	0	11·3	n.s.
18/5 - 21/7	144·6*	28·0	115·6*	a 96·5 b 160·1

a L.S.D. between treatments means (P = 0·05)

b " " " " (P = 0·01)

* significant (P = 0·05)

** significant (P = 0·01)

The larger Staphylinidae species O. rugosus occurred mainly during the first part of the season. The number captured in the surface treatment was also consistently lower than both the control and the sub-surface treatment (Fig. 12). The mean number captured in the control, the sub-surface and the surface treatments till July 21 was 70, 61 and 36.[1] The mean catch in the surface treatment was significantly lower (P = 0·05) compared with the control, the difference between the surface and the sub-surface was very near to the significance at 5% level; while the difference between the sub-surface and the control treatment was non-significant.

The species Lesteva longelytrata Goez. occurred in smaller numbers during the end of May and the beginning of June and was affected by the diazinon treatments as were the other Staphylinidae species. The population of this species increased remarkably in the field starting from the second week of October (Fig. 13), but that was after the oviposition of the cabbage root fly has ceased.

The species Oxytelus insecatus Grav., O. fulvipes Er., O. inustus Grav., Tachyporus obtusus L., T. solutus Er., Tachinus rufipes Deg., Philonthus rotundicollis Mén., P. laminatus Cr., P. mannerheimi Fauv., Gyrohypnus punctulatus Gz. and Quedius semiaeneus St. occurred in small numbers during the season. The total number of each group of Staphylinidae captured in each of the two treatments and the control during the periods from May 18 till July 21 and from August 9 till October 23 is given in Table 6.

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1. L.S.D. between the means (P = 0·05) is 25·7.

Fig. 11 **Atheta spp.**

1965

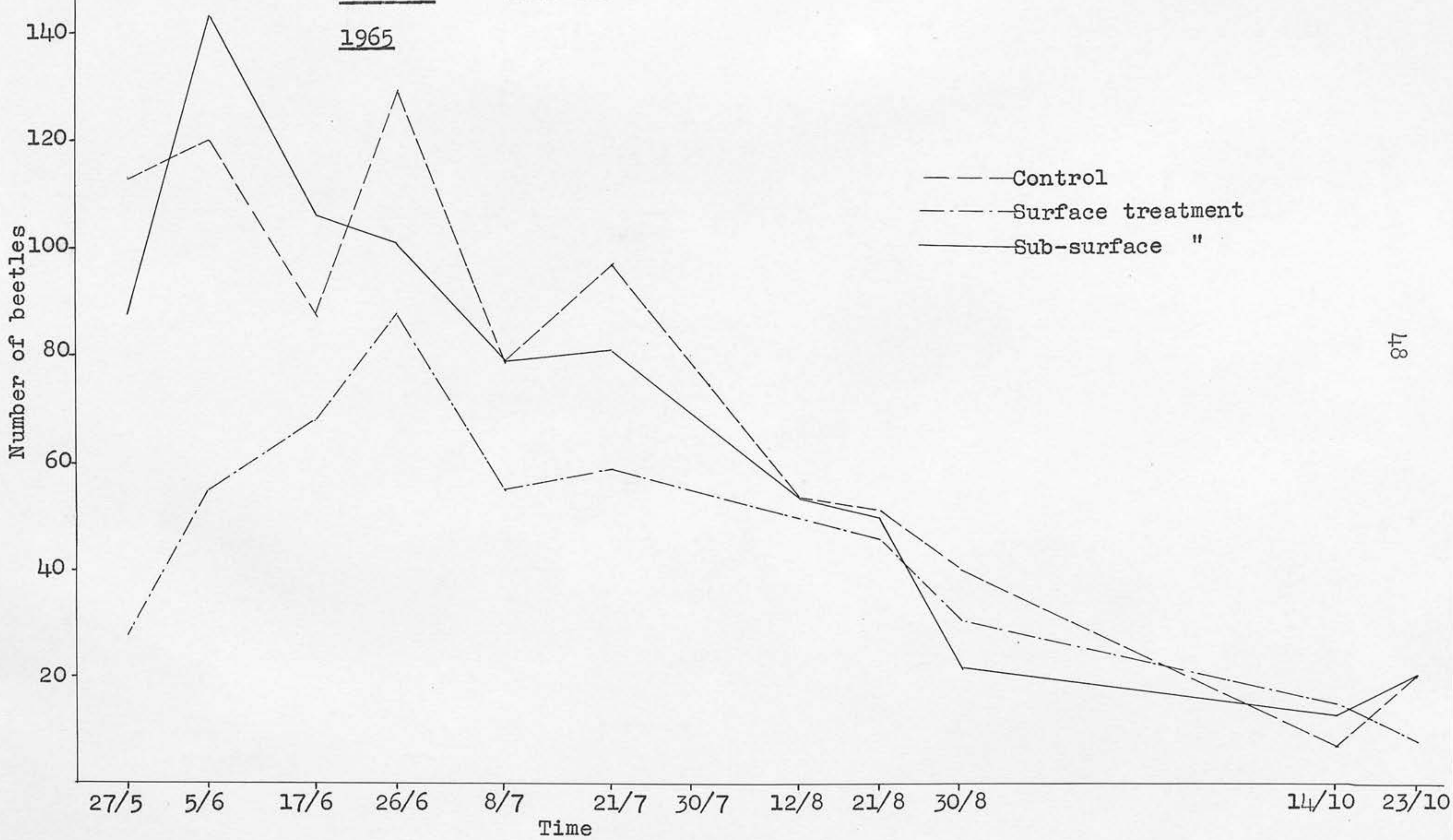
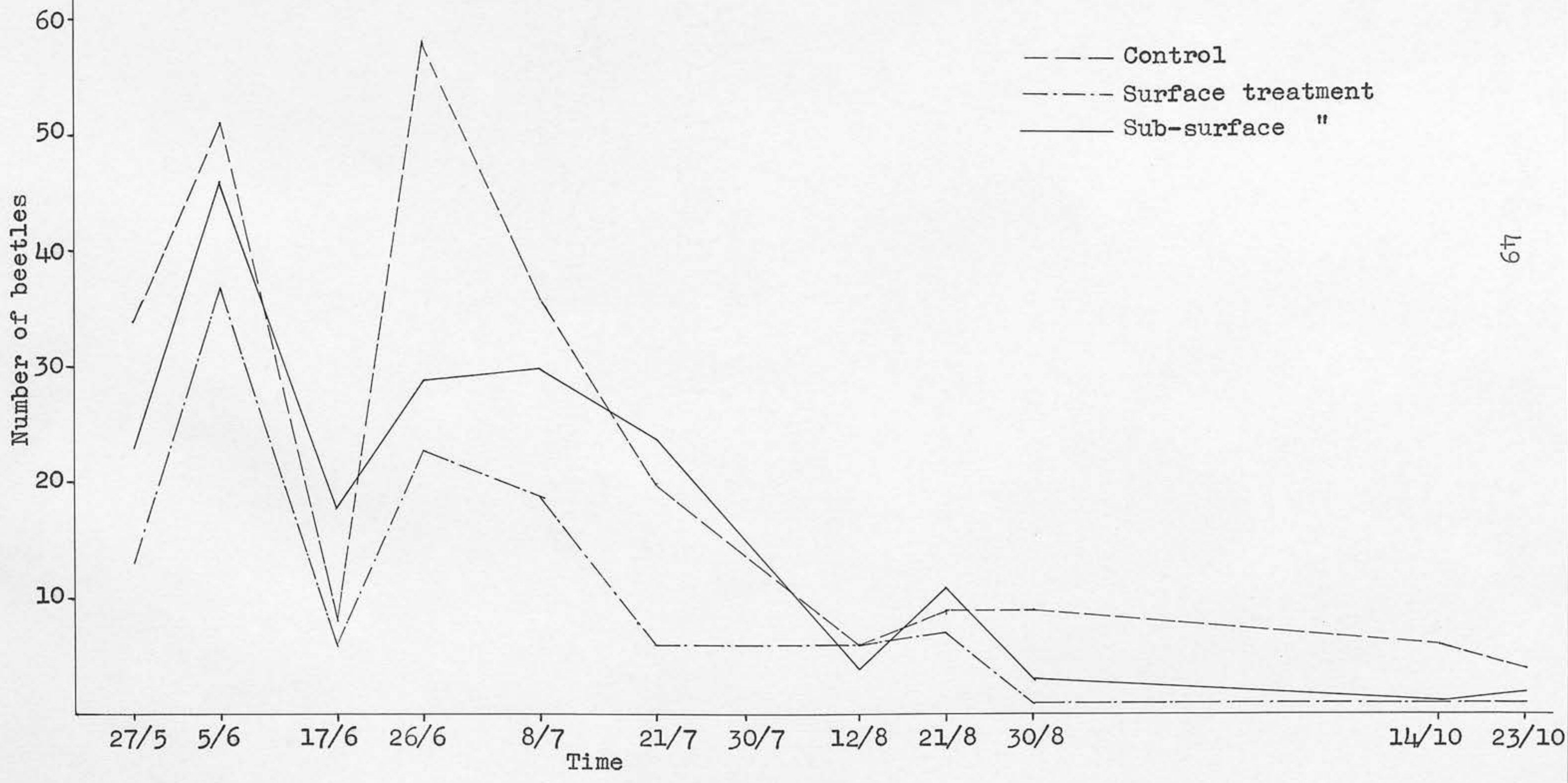


Fig. 12 O. rugosus

1965



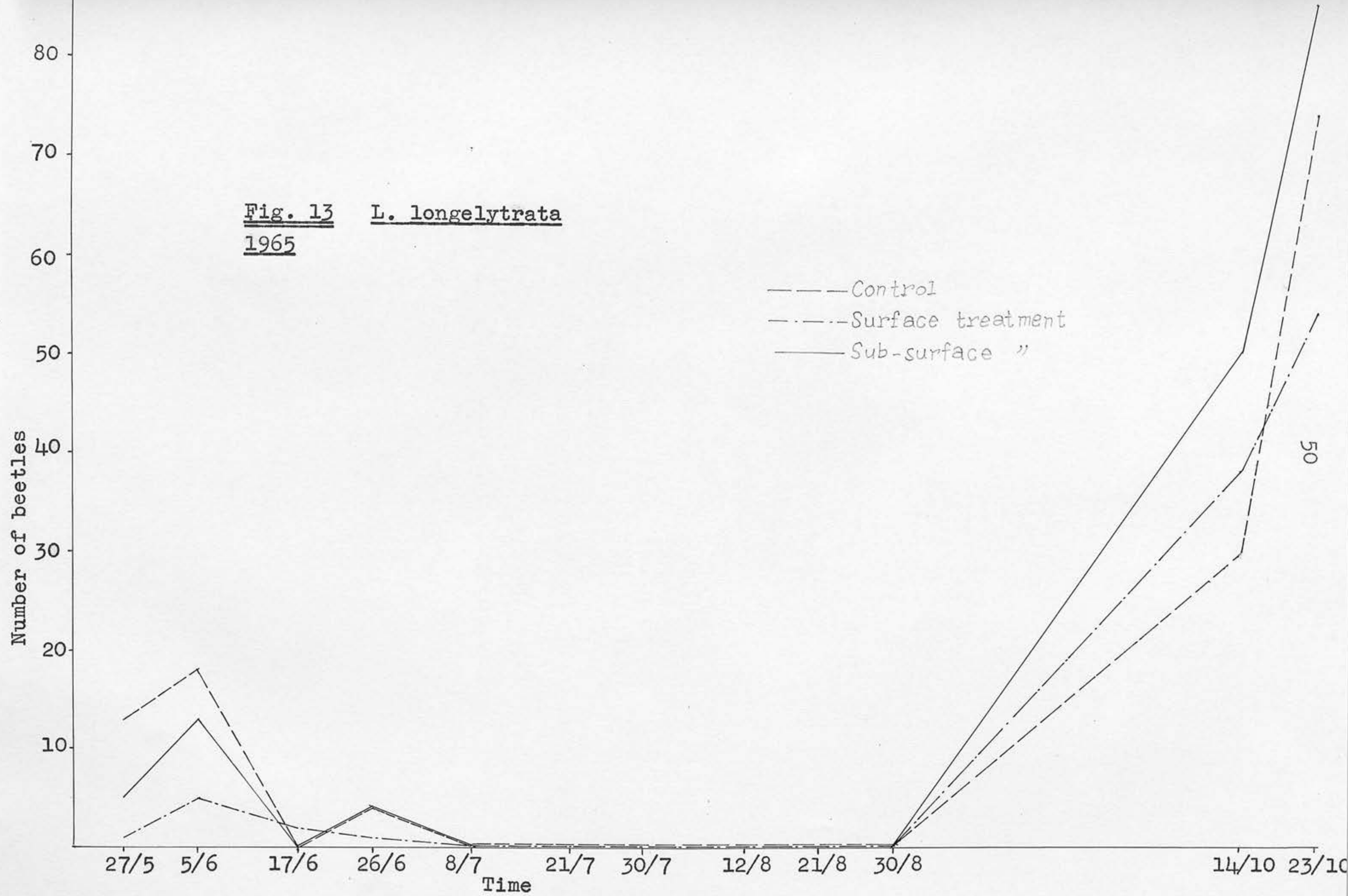


Fig. 13 L. longelytrata
1965

TABLE 6

Total number of each group of Staphylinidae captured in the surface, the sub-surface diazinon treatments and the control during the 1965 experiment.

	May 18 till Jul.21			Aug. 9 till Oct.23		
	Con.	S.	S.S.	Con.	S.	S.S.
Atheta spp.	643	330	584	216	188	206
O. rugosus	211	108	182	37	21	23
L. longelytrata	35	9	22	104	92	135
Philonthus spp.	5	7	4	7	8	8
T. rufipes	10	6	12	1	2	4
Tachyporus spp.	12	12	17	3	2	0
Other species	9	19	20	23	26	16
TOTAL	925	491	841	391	339	392

The species Hypnoidus riparius (Fab.) (Elateridae), Aclypea opaca (L.) (Silphidae), Helophorus porculus Bedel (Hydrophilidae) Aphodius rufipes L. (Scarabaeidae), Agonum mulleri (Hbst.) (Carabidae) were also taken by the traps.

B - Chlorfenvinphos:

The organophosphorus compound chlorfenvinphos or 2-chloro-1-(2,4-dichlorophenyl)vinyl diethyl phosphate is known commercially by the name Birlane. This chemical has been shown by Trought and Heath (1965) to be extremely active against the cabbage root fly at low rates of applications and to be sufficiently persistent to give control for the whole season. Further work by Wright (1965) showed that 10% chlorfenvinphos granules applied in 3 inch wide band at 2 lb. a.i. per acre gave a high level of root fly control to the swede crop, not only in the year of application, but also in two successive turnip crops drilled in the same planting positions during the following years.

In the present investigation the 10 per cent chlorfenvinphos granules were applied at the rate of 0·5 grammes per plant. The pit-fall traps were placed in the field on May 19 and were examined every 3 days till September 21. The effect of the surface and the sub-surface chlorfenvinphos treatments on the number of Carabidae and Staphylinidae trapped in the field was as follows:

1- On Carabidae:

By using a persistent insecticide it was expected that the mortality of the predatory beetles would be extended into a longer period during the season. But the results of the present experiment showed that the insecticide chlorfenvinphos had very little or no effect on the Carabid beetles in the field. It is shown in Fig.14 that the number of Carabid captured at 3 day intervals in the surface and the sub-surface treatments did not differ from that of the control untreated plots.

The mean number of Carabidae captured per plot during 9 day intervals in the surface, the sub-surface and the control treatments is shown in Table 7. It is shown in the table that there was no significant difference between any of the chlorfenvinphos treatments and the control. The number of each group of Carabid trapped over 9 day periods throughout the season is shown graphically in Figures 15 to 19. It is apparent from these figures and from comparing each of them with the corresponding figures of 1965, that

Fig. 14 Carabidae
1966

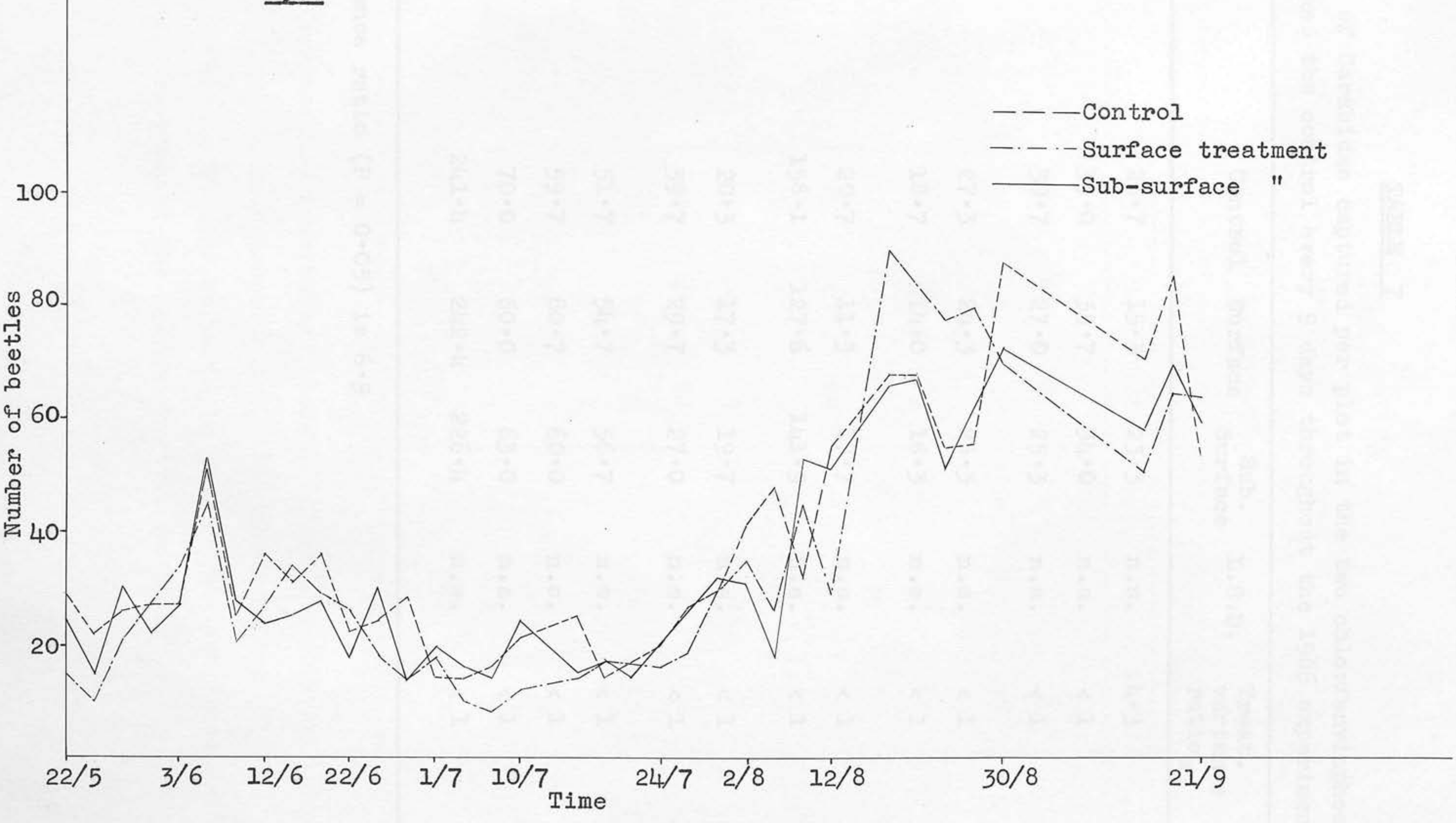


TABLE 7

Mean number of Carabidae captured per plot in the two chlorfenvinphos treatments and the control every 9 days throughout the 1966 experiment

	Control	Surface	Sub. Surface	L.S.D.	Treat. variance ratio[a]
19/5 - 28/5	25·7	15·3	23·3	n.s.	4·3
28/5 - 6/6	35·0	35·7	34·0	n.s.	< 1
6/6 - 15/6	30·7	27·0	25·3	n.s.	< 1
15/6 - 21/6 22/6 - 25/6	27·3	24·3	25·3	n.s.	< 1
25/6 - 4/7	18·7	14·0	16·3	n.s.	< 1
4/7 - 10/7 13/7 - 16/7	20·7	11·3	17·7	n.s.	< 1
TOTAL	158·1	127·6	141·9	n.s.	< 1
16/7 - 19/7 21/7 - 27/7	20·3	17·3	19·7	n.s.	< 1
27/7 - 5/8	39·7	29·7	27·0	n.s.	< 1
6/8 - 12/8 15/8 - 18/8	51·7	54·7	56·7	n.s.	< 1
18/8 - 27/8	59·7	80·7	60·0	n.s.	< 1
15/9 - 21/9	70·0	60·0	63·0	n.s.	< 1
TOTAL	241·4	242·4	226·4	n.s.	< 1

a The variance ratio (P = 0·05) is 6·9

TABLE 8

Total number of each group of Carabidae captured in the surface, the sub-surface chlorfenvinphos treatments and the control during the 1966 experiment

	May 19 till Jul.16			Jul. 16 till Sep. 21		
	Con.	S.	S.S.	Con.	S.	S.S.
B. guttula, B. lampros	115	93	126	4	4	2
T. obtusus	29	20	38	509	521	500
B. tetracolum, B. bruxellense	69	75	74	40	29	37
N. brevicollis	113	103	84	74	76	74
Amara spp.	52	30	28	68	97	51
L. pilicornis	29	10	8	9	8	6
Pterostichus spp.	15	25	23	27	30	33
C. fossor	33	15	20	9	8	9
P. assimilis	0	0	0	13	8	13
Calathus spp.	2	0	1	6	5	1
Notiophilus spp.	4	3	3	4	2	2
Other species	13	9	21	9	9	5
TOTAL	474	383	426	772	797	733

the Carabid species are remarkably tolerant to the chlorfenvinphos compared with the diazinon insecticide. The total number of each group of Carabid beetles captured in each of the two treatments and the control throughout the season is given in Table 8.

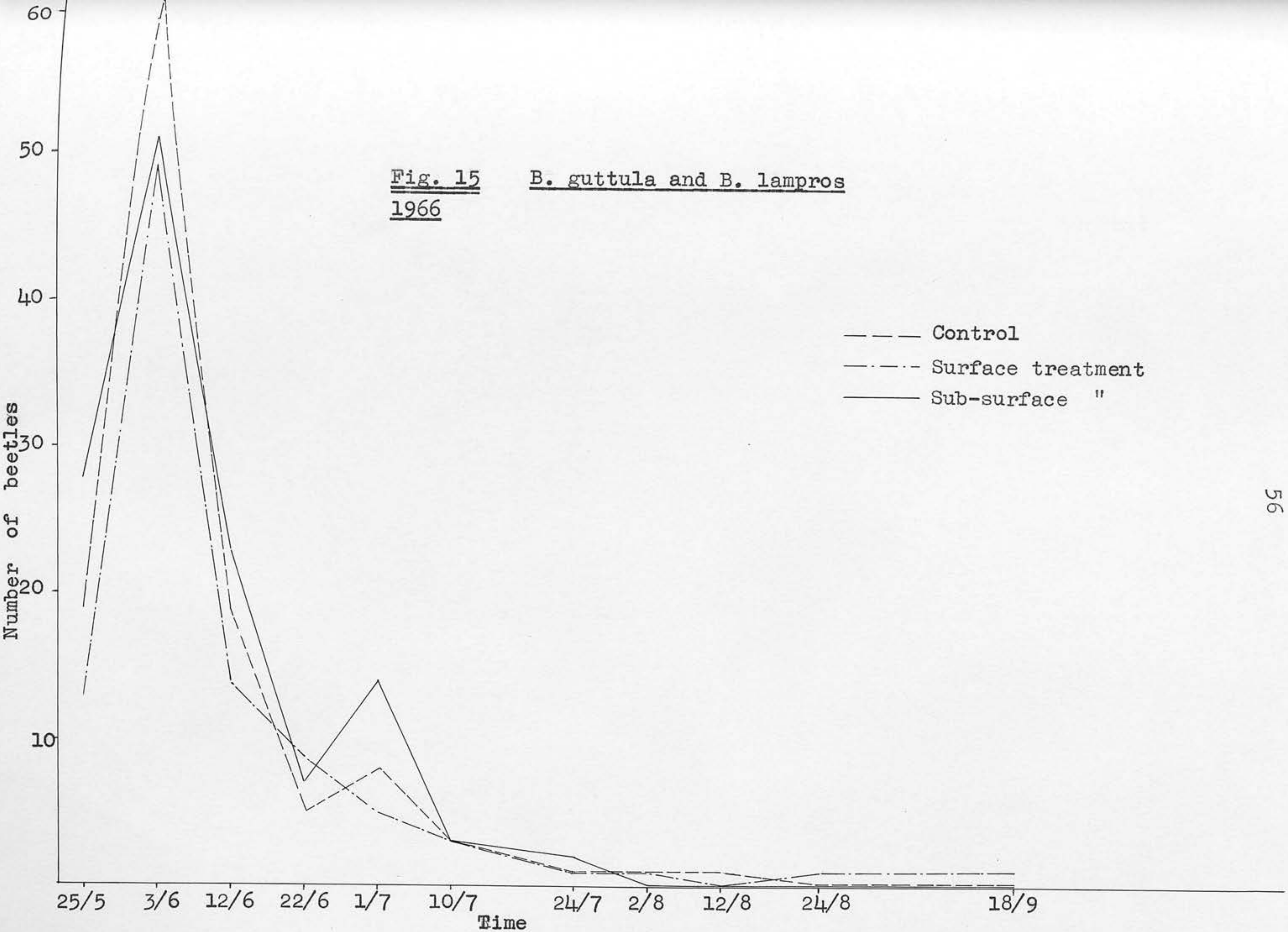


Fig. 15 B. guttula and B. lampros
1966

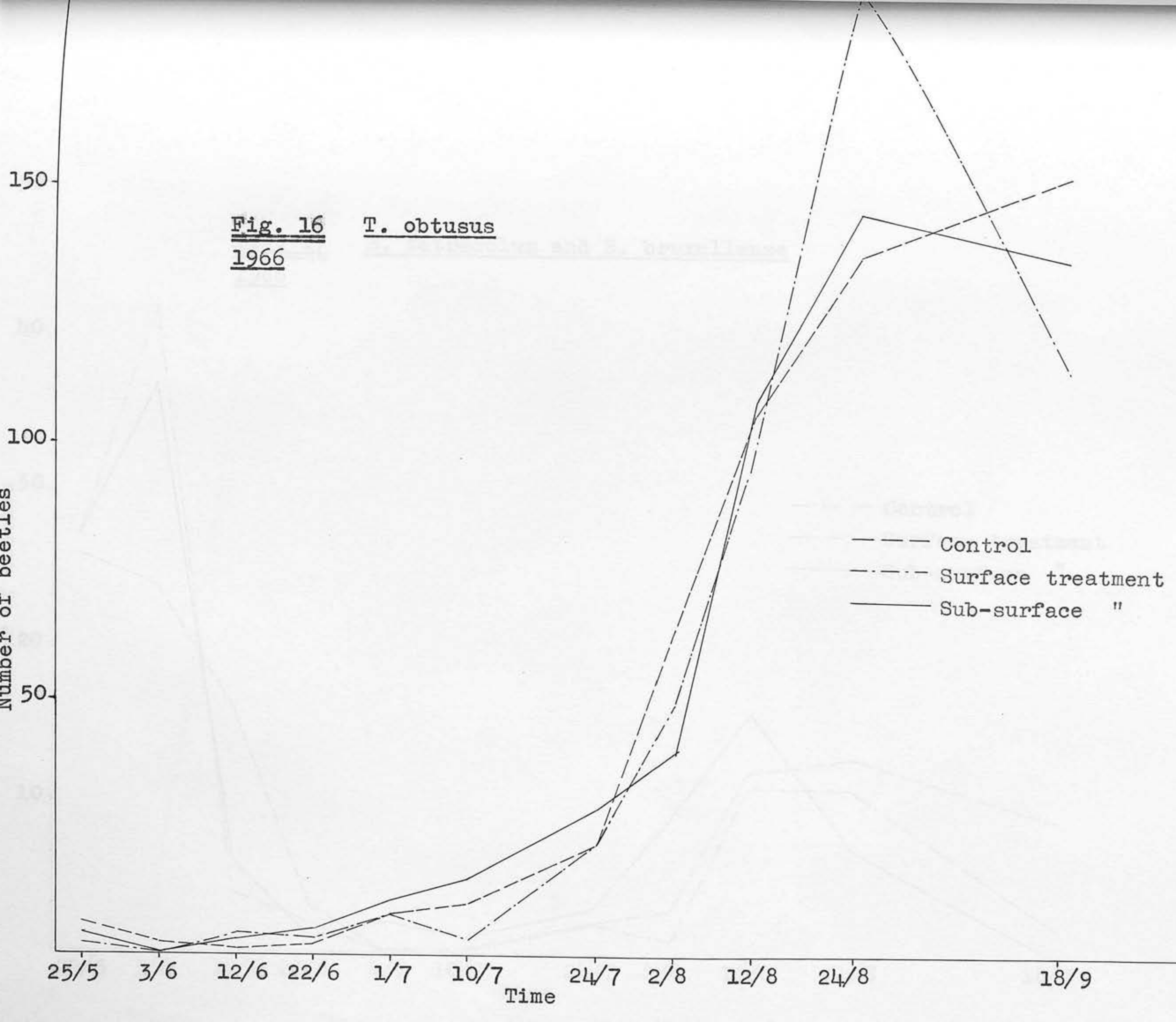
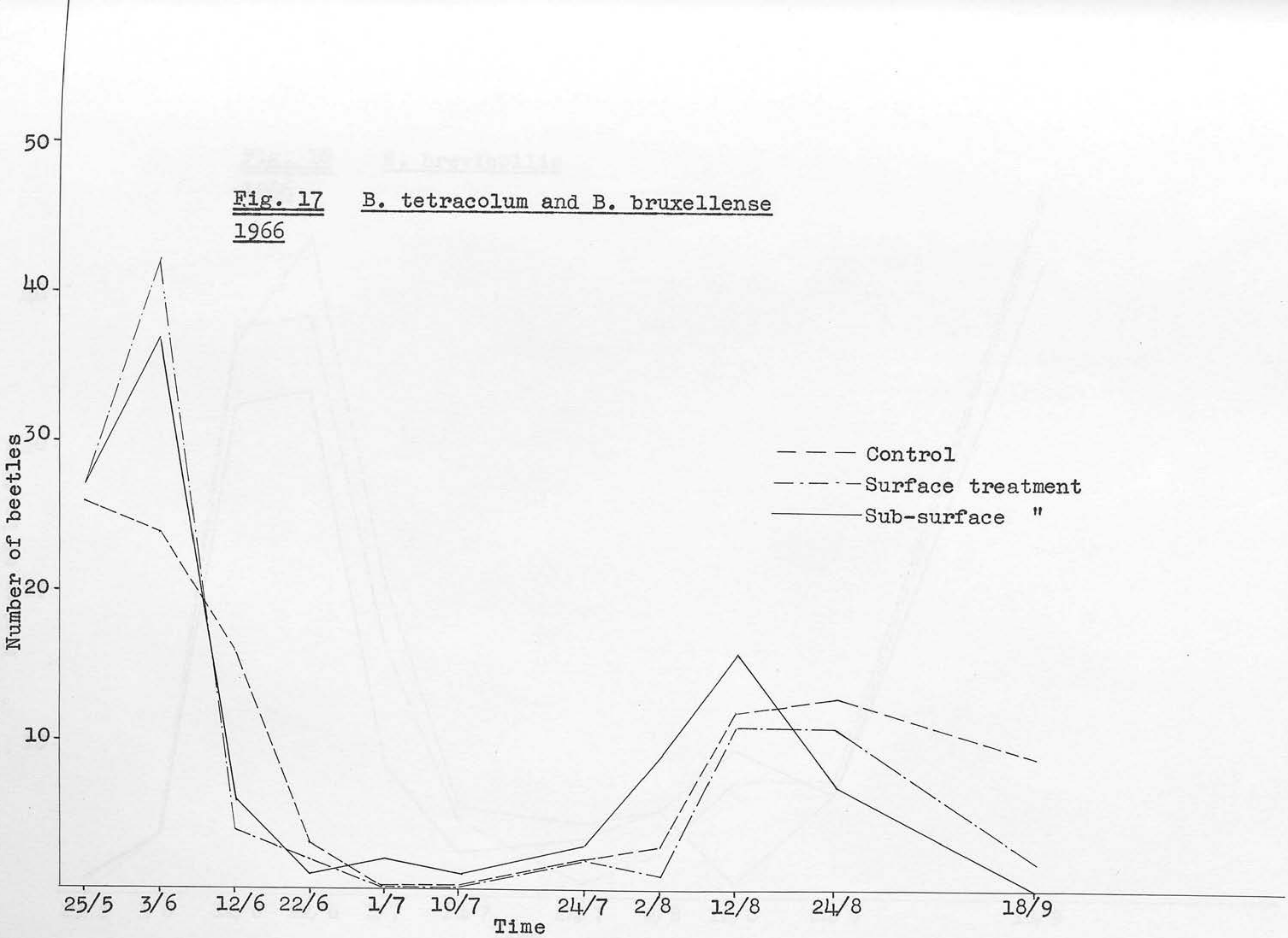


Fig. 16 T. obtusus
1966

Fig. 17 **B. tetracolum and B. bruxellense**
1966



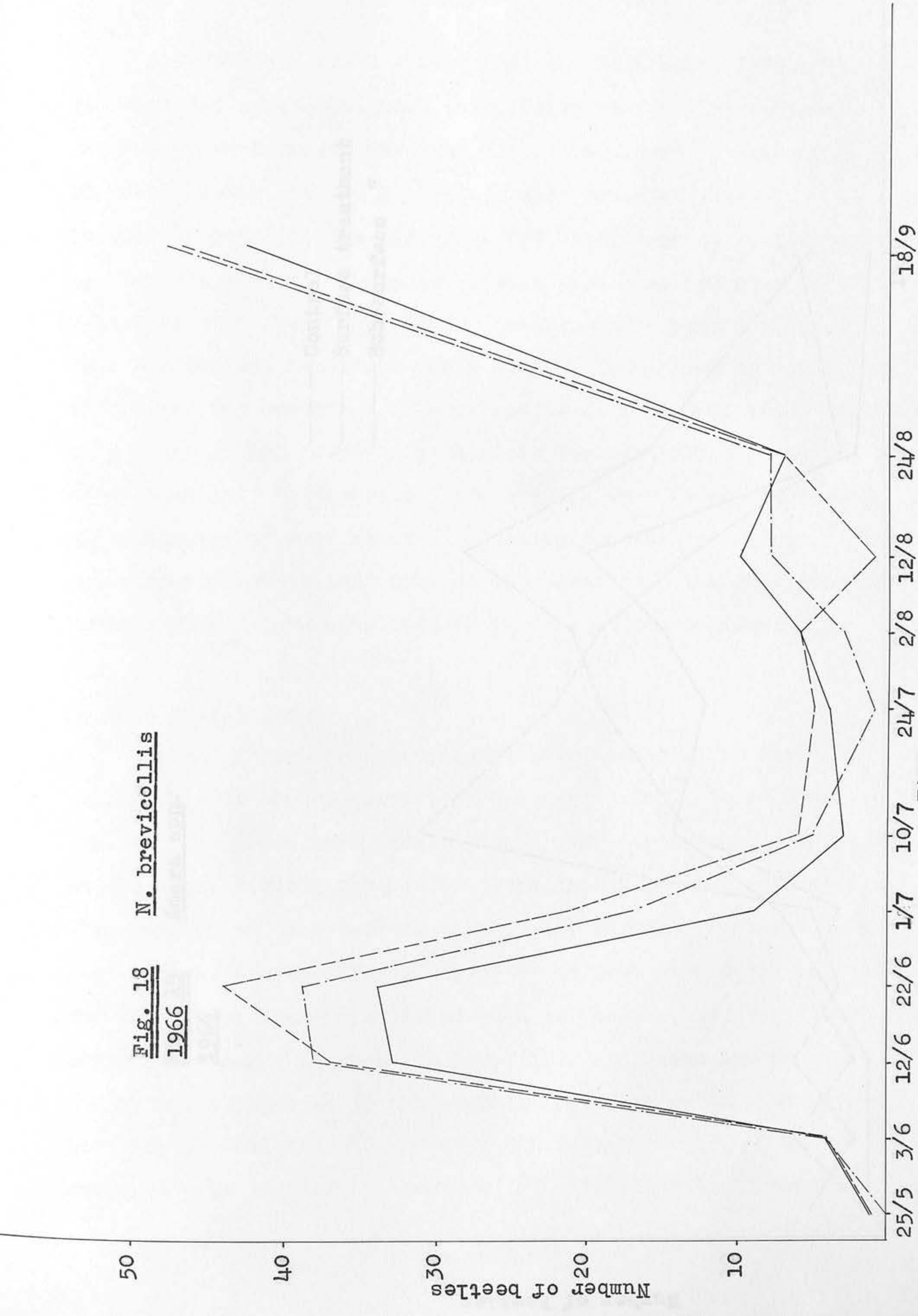
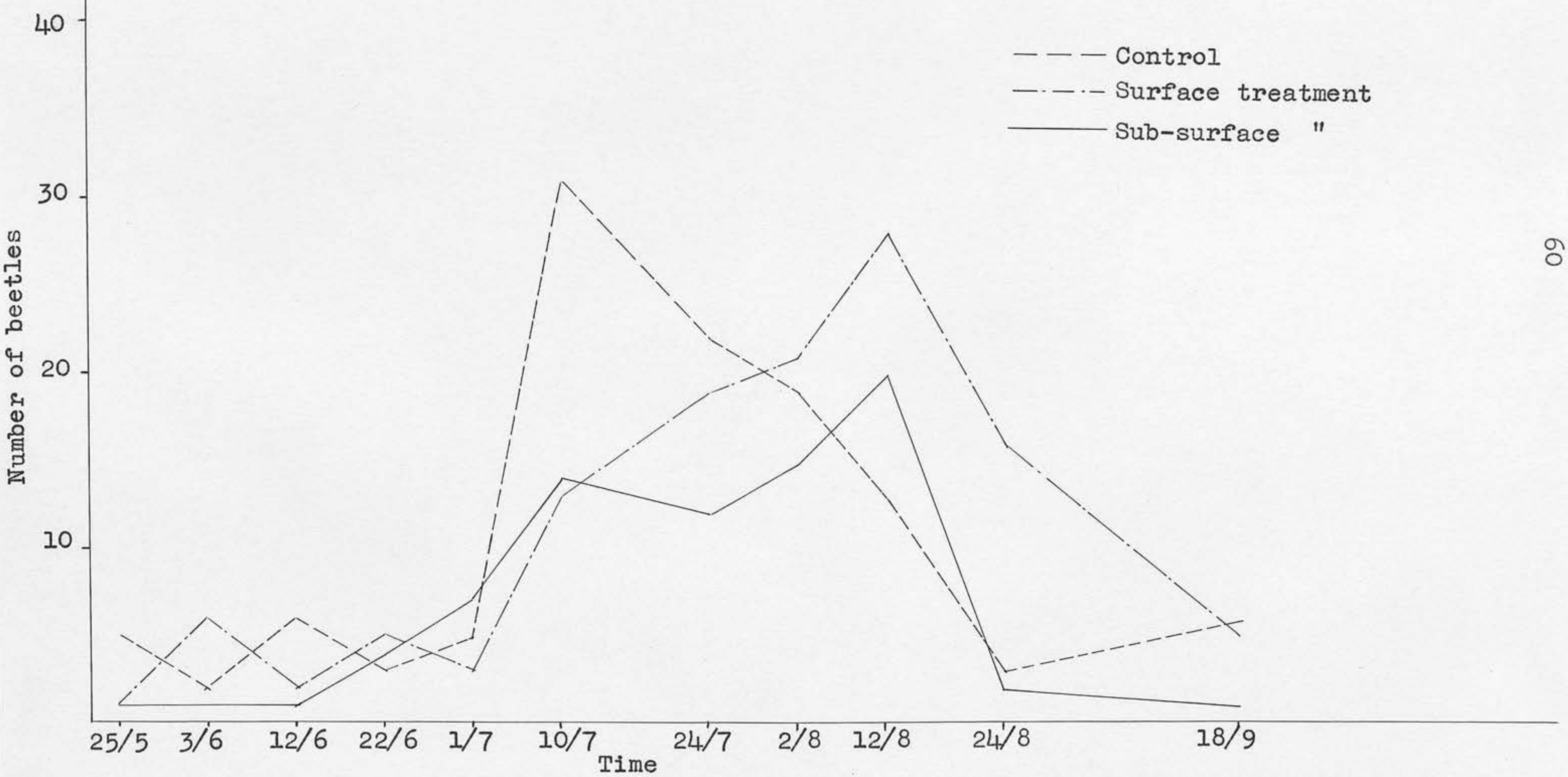


Fig. 18 N. brevicollis
1966

<u>Fig. 19</u> <u>Amara spp.</u>
<u>1966</u>



A laboratory trial showed that the Carabids would readily die when fed on contaminated eggs collected from the surface chlorfenvinphos treatment. 25 eggs were placed in each of 10 petri dishes and two B. guttula were released in each. A further 10 petri dishes were prepared using eggs collected from the control plots. The petri dishes were examined every day. 7 beetles were found dead after feeding on the eggs collected from the surface treatment and 9 died on the following day. One week after the beginning of the experiment only 3 of these beetles were found living compared with 16 in the control. It should be noted that in this experiment the beetles were forced to feed on the contaminated eggs as no alternative food was available. This experiment suggests that some of the Carabids in the chlorfenvinphos treated plots might have died by feeding on contaminated eggs.

2- On Staphylinidae:

On the other hand the Staphylinidae seemed to be quite susceptible to the chlorfenvinphos insecticide. It is shown in Fig. 20 that there were nearly always more Staphylinids captured in the control plots than in both the insecticidal treatments, and also more in the sub-surface than in the surface treatment. The mean number of Staphylinids captured per plot over 9-day periods throughout the season is illustrated in Table 9, and the difference between the means is shown in Table 10. The mean number of Staphylinids captured in the surface treatment during the period from May 19 till July 16 was significantly lower ($P = 0{\cdot}01$) compared with that of the control, and significantly lower ($P = 0{\cdot}05$)

Fig. 20 Staphylinidae

1966

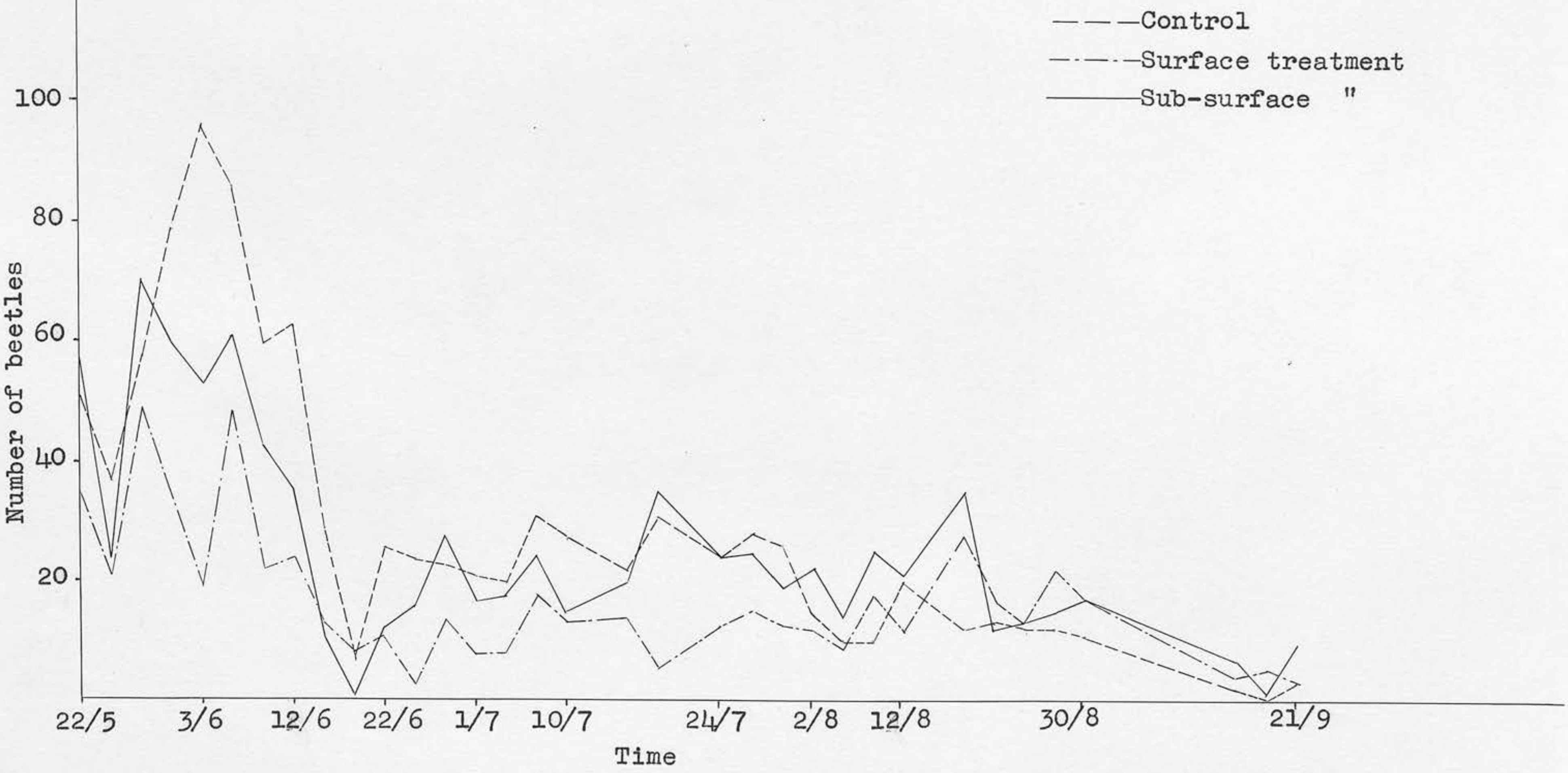


TABLE 9

Mean number of Staphylinidae captured per plot in the two chlorfenvinphos treatments and the control every 9 days throughout the 1966 experiment.

Period	Control	Surface	Sub Surface	L.S.D.	Treat. variance ratio$_c$
19/5 - 28/5	48·7	35·0	49·7	n.s.	2·8
28/5 - 6/6	87·0	34·0	58·0	a 31·8 b 52·7	10·7*
6/6 - 15/6	50·7	19·7	30·0	a 17·1 b 28·4	13·2*
15/6 - 21/6 22/6 - 25/6	19·0	7·3	9·7	a 7·3 b 12·1	10·1*
25/6 - 4/7	21·3	10·0	20·7	n.s.	4·9
4/7 - 10/7 13/7 - 16/7	23·7	15·3	19·7	n.s.	2·6
TOTAL	250·4	121·3	187·8	a 57·9 b 86·1	19·1**
16/7 - 19/7 21/7 - 27/7	27·7	11·3	28·0	n.s.	2·7
27/7 - 5/8	17·0	11·3	18·3	n.s.	1·9
6/8 - 12/8 15/8 - 18/8	14·0	19·3	27·0	n.s.	1·4
18/8 - 27/8	12·3	17·7	13·3	n.s.	1·3
15/9 - 21/9	1·7	4·0	5·7	n.s.	< 1
TOTAL	72·7	63·6	92·3	n.s.	1·0

a L.S.D. between treatments means (P = 0·05)

b " " " " (P = 0·01)

c The variance ratio (P = 0·05) is 6·9 and (P = 0·01) is 18

* significant (P = 0·05)

** significant (P = 0·01)

TABLE 10

The difference between the mean number of Staphylinidae captured per plot in the two chlorfenvinphos treatments and the control every 9 days from May 19 till July 16.

Period	Con. - Surface	Con. - Sub-S.	Sub.S.- Surface	L.S.D.
19/5 - 28/5	13·7	- 1·0	14·7	n.s.
28/5 - 6/6	53·0**	29·0	24·0	a 31·8 b 52·7
6/6 - 15/6	31·0**	20·7*	10·3	a 17·1 b 28·4
15/6 - 21/6 22/6 - 25/6	11·7*	9·3*	2·3	a 7·3 b 12·1
25/6 - 4/7	11·3	0·7	10·7	n.s.
4/7 - 10/7 13/7 - 16/7	8·3	4·0	4·3	n.s.
19/5 - 16/7	129·0**	62·7*	66·3*	a 57·9 b 96·1

a L.S.D. between treatments means (P = 0·05)

b " " (P = 0·01)

* significant (P = 0·05)

** significant (P = 0·01)

than that of the sub-surface treatment. The mean of the sub-surface treatment was also significantly lower (P = 0·05) than that of the control.

The smaller Staphylinidae, e.g. Atheta spp. (Fig. 21) formed 62 per cent of the total Staphylinidae captured throughout the season. The mean number of beetles belonging to this group captured per plot during the period from May 19 till July 16 in the control, the sub-surface, and the surface treatments was 146, 119 and 79[1] respectively. The catch in the sub-surface treatment was not significantly different from that of the control, while the catch in the surface treatment was significantly lower (P = 0·05) compared with that of the control.

The chlorfenvinphos treatments seem to have affected the larger species O. rugosus (Fig. 22) more than any other species. The mean number captured during this period in the control, the sub-surface and the surface treatments was 79, 45 and 27[2] respectively. The catch in each of the two treatments being significantly lower (P = 0·01) than that of the control. The catch in the surface treatment was also significantly lower (P = 0·01) compared with that of the sub-surface treatment.

Many fewer O. rugosus were captured from July 16 till September 21 but the effect of the insecticide applied on the surface could still be detected. The mean number of beetles captured during this period in the control, the sub-surface and the surface treatments was 22·3, 23·3 and 8·6[3] respectively, the

1. L.S.D. (P=0·05) is 56.
2. L.S.D. (P=0·01) is 18.
3. L.S.D. (P=0·05) is 14·1.

Fig. 21 Atheta spp.
1966

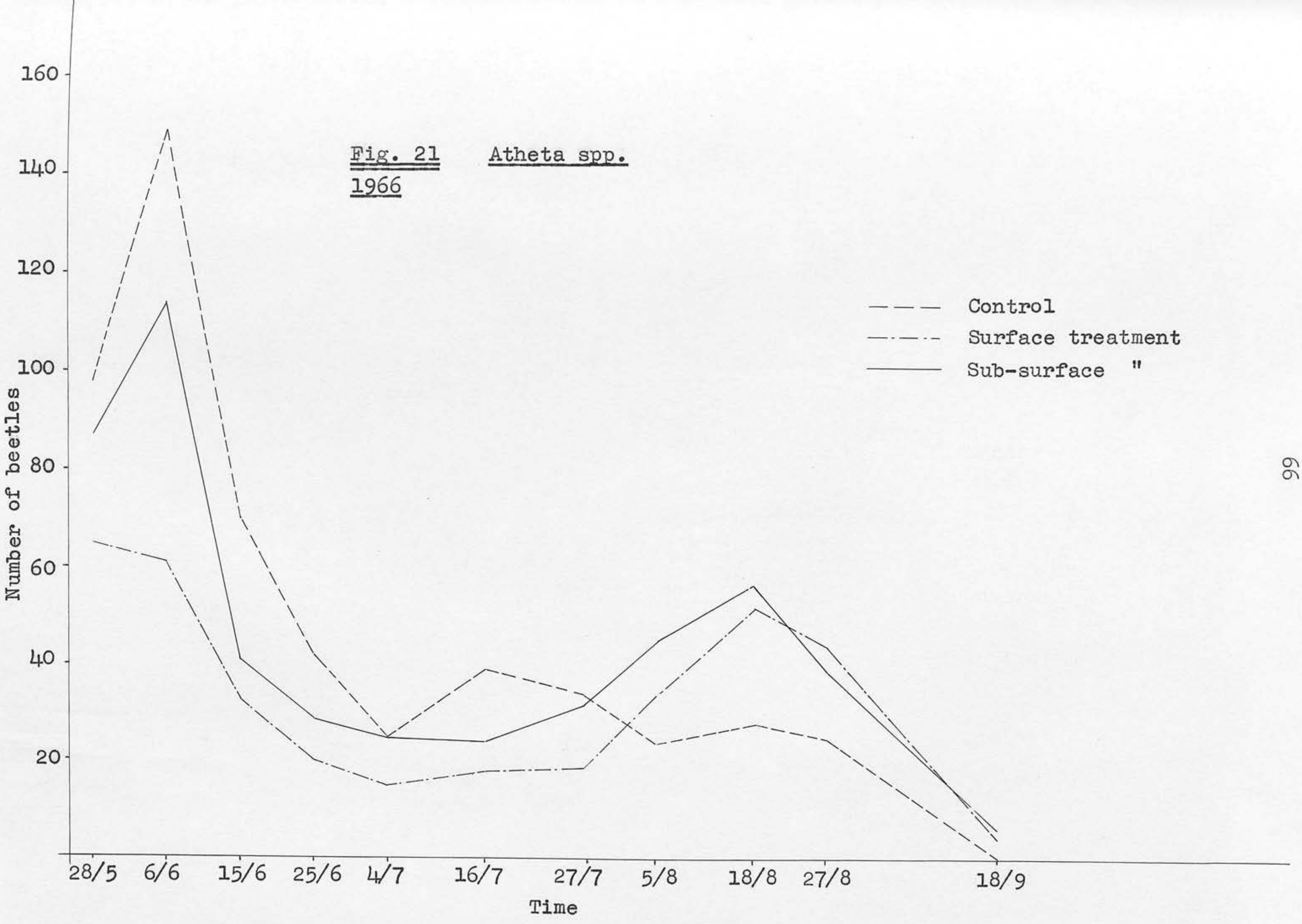
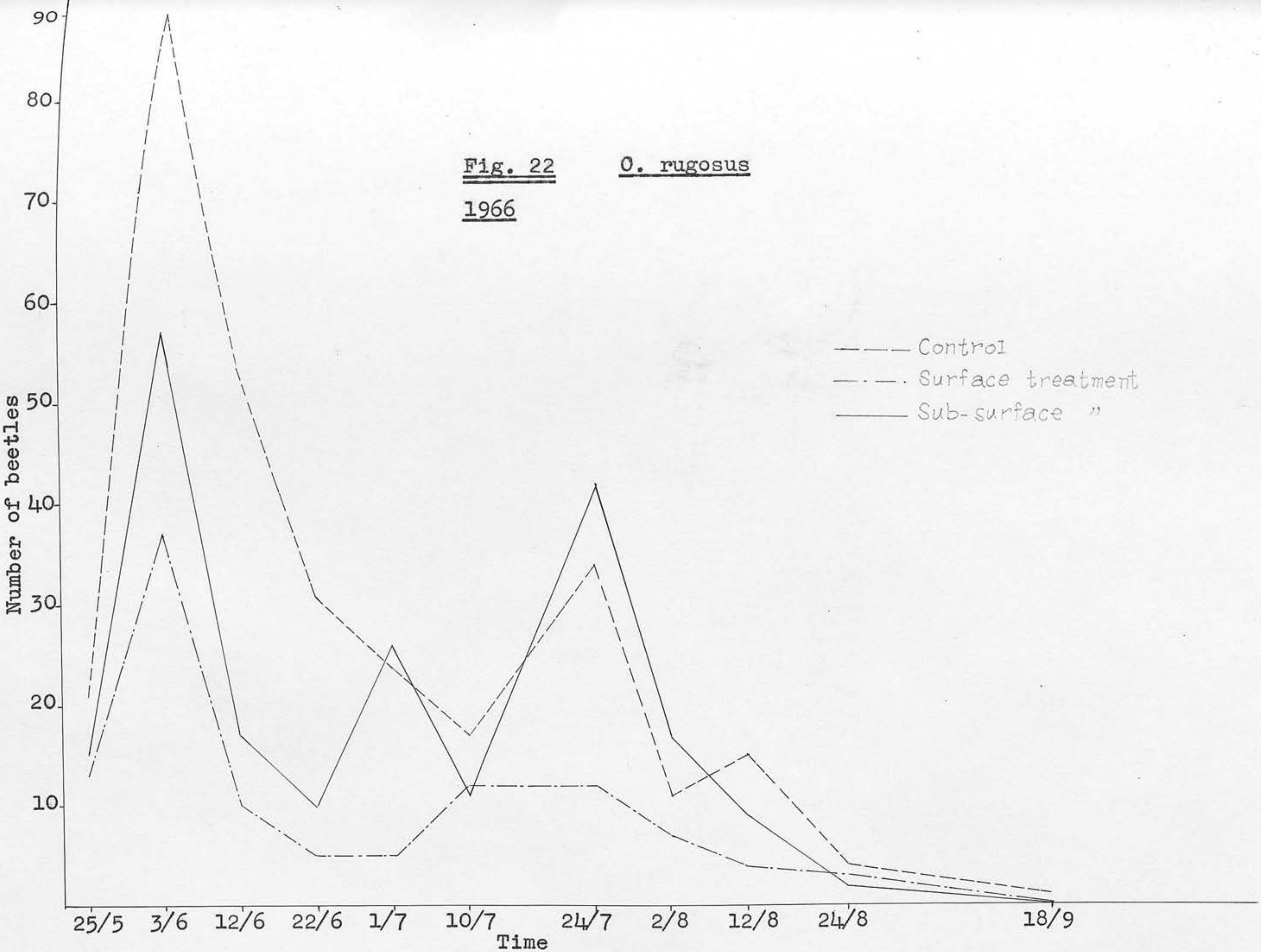


Fig. 22 **O. rugosus**

1966



difference between the surface and the control being very near to significance. The difference between the surface and the sub-surface treatments was significant (P = 0·05).

This result shows that the chlorfenvinphos application on the surface of the soil not only affected the beetles of this species to a greater extent than the sub-surface treatment, but also the effect continued for a longer time. The number of each group of Staphylinidae captured in each of the two treatments and the control is given in Table 11.

TABLE 11

Total number of each group of Staphylinidae captured in the surface, the sub-surface chlorfenvinphos treatments and control during the 1966 experiment

	May 19 till Jul.16			Jul. 16 till Sep. 21		
	Con.	S.	S.S.	Con.	S.	S.S.
Atheta spp.	437	239	357	125	154	187
O. rugosus	237	82	136	67	26	70
L. longelytrata	17	7	20	0	0	0
Philonthus spp.	25	13	13	9	7	9
T. rufipes	24	19	21	2	5	2
Tachyporus spp.	6	4	6	9	5	5
Other species	5	0	10	17	11	21
TOTAL	751	364	563	229	208	294

Laboratory Experiments:

The field experiments showed that the application of diazinon granules in 1965 reduced the number of Carabid beetles significantly compared with the control untreated plots , while in 1966 the application of chlorfenvinphos granules had very little or no effect on the Carabid beetles compared with the control plots.

Therefore laboratory experiments were carried out to examine the effect of these chemicals on these important predatory beetles. Biscuit tins (9 x $8\frac{1}{2}$ x $4\frac{1}{2}$ inches) were used for this purpose. A three-inch layer of soil completely free from beetles, was added to each tin and the insecticides were applied in the middle (Plate 5). The sides of the tins were cleaned thoroughly and coated with a thin layer of silicone fluid (F111/100). Primary

Plate 5. Insecticide granules applied around a cabbage plant in a biscuit tin.

experiments showed that it was not possible for the beetles to climb up provided that the sides were kept dry. A hand sprayer was used to moisten the soil every two or three days.

Experiment 1

Six biscuit tins each treated as follows were prepared:

(a) 0·5 grammes of 10% chlorfenvinphos granules were applied on the top of the soil.

(b) 0·5 grammes of 10% chlorfenvinphos granules were applied at a depth of $\frac{1}{2}$ - 1 inch under the surface of the soil.

(c) untreated control.

Five B. guttula beetles were released in each tin one week after the application of the insecticide. Daily observation revealed that most of the beetles were living. The soil in each tin was then carefully examined for dead and living beetles. The results are shown in Table 12. There is no significant difference between the two treatments and the control, indicating that the insecticide has very little or no effect on the beetles.

TABLE 12

Living and dead B. guttula found six days after their release in the chlorfenvinphos treatments and the control

Treatments	Replicates 1	2	3	4	5	6	Total
Control	5 0	4 1	3 2	2 2	5 0	3 0	22 Living 5 Dead
Surface	4 0	3 1	2 1	4 0	2 2	4 1	19 Living 5 Dead
Sub-Surface	5 0	4 0	3 2	3 1	4 0	5 0	24 Living 3 Dead

Experiment 2

Nine sets of biscuit tins were prepared as follows:

(a), (b) and (c) as experiment 1.

(d) 0·8 grammes of 5% Diazinon granules applied on the top of the soil.

(e) 0·8 grammes of 5% Diazinon granules applied at a depth of ½ - 1 inch under the surface of the soil.

Five T. obtusus beetles were released into each tin the same day the insecticide were applied. The treatments (d) and (e) were repeated. With a little brush it was possible to find a large percentage of the beetles on the surface of the soil or very near to it. A record of these counts is shown in Table 13.

TABLE 13.

Living and dead T. obtusus found in the insecticide treatments and the control

Treatments	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
								DAYS										
Diazinon S.	9	3	0 Living															
	27	33	all dead															
Diazinon S.S.	36	32	12		7		1	0 Living										
	2	4	18		28		33	all dead										
Diazinon S.	5	1	0 Living															
	30	37	all dead															
Diazinon S.S.	32	29	17	10		4	0 Living											
	0	5	9	22		25	all dead											
Chlorfenvin-phos S.			30		26		29			29			29					28 Living
			0		0		0			2			2					13 Dead
Chlorfenvin-phos S.S.			32		29		30			29			26					27 Living
			0		0		0			1			3					8 Dead
Control			30		41		32			28			36					30 Living
			0		0		0			0			2					8 Dead

The results of this experiment reveal the wide gap between these two insecticides. While the surface treatment of the diazinon killed most of the beetles during the first 24 hours, the beetles in the chlorfenvinphos treatment lived till the end of the 18 days experiment. The mortality of the beetles in the sub-surface treatment, however, depends entirely on the condition of the soil and the amount of covering it provides to the insecticide. In this case the beetles started dying rapidly after three days in the sub-surface treatment of diazinon, and they were all killed after one week. Similar experiments using the following larger species of beetles gave similar results. N. brevicollis, Amara spp., L. pilicornis, Pterostichus spp. and H. riparius. Very few beetles were found dead at the end of the 18 days trial with chlorfenvinphos and were no different from the control, while most of the beetles were found dead in the diazinon trial after 24 hours.

The effect of these insecticides was further examined by forcing each individual beetle to come into contact with the moist granular insecticide applied on the surface of the soil as previously described. The beetles were then kept in groups of five in plastic containers. The mortality was recorded as indicated in Table 14. The results of this experiment show that nearly all the beetles treated with the diazinon insecticide died within one hour of the treatment. Only six out of the twenty-five beetles treated with the chlorfenvinphos insecticide died within one week of the treatment, compared with three from the control untreated beetles.

Treatments	Time 29/9 2·0 p.m.	2·30	2·45	3·0	3·30	4·45 p.m.	30/9	1/10	2/10	3/10	4/10	6/10
Diazinon	4	11	21	23	24			25				
Chlorfenvinphos				1	2		3		5			6
Control										1		3

The number of T. obtusus dead after coming into contact with the insecticides

TABLE 14.

II. Predation by Carabidae and Staphylinidae on the egg stage of the cabbage root fly and the effect of insecticides thereon:

In the present investigation Carabids and Staphylinids were observed to feed on cabbage root fly eggs both in earthenware pots (Plate 6) and in petri dishes. Plates 7, 8 and 9 show eggs destroyed in petri dishes by B. gutulla, A. gregaria and O. rugosus respectively. Two undamaged eggs were included in each plate for comparison. Miles (1952), Wishart et al. (1956) and Hughes (1959b) recorded similar observations.

The Carabids B. guttula, T. obtusus, Amara spp., the Staphylinids Oxytelus spp. and Atheta spp., were considered the most important predators as they were observed to feed very actively on the eggs, while the Carabids Bembidion spp., Pterostichus spp., N. brevicollis and the Staphylinid Philonthus spp., were less active in this respect.

Predation by beetles on the egg stage and the effects of diazinon and chlorfenvinphos were studied during the 1965 and 1966 field experiments respectively. Egg samples were taken every three days from plants with and without barriers. The technique used for setting out the barriers and sampling for eggs has previously been described.

A - 1965 experiment:

Sampling for eggs was started on May 29 and continued till September 26. Records of full eggs and empty chorions were made. The chorions from hatched eggs were counted. The unhatched eggs were then kept on moist filter paper for 6 days at 20°C and the

Plate 6. B. guttula released with cabbage root fly eggs in an earthenware pot.

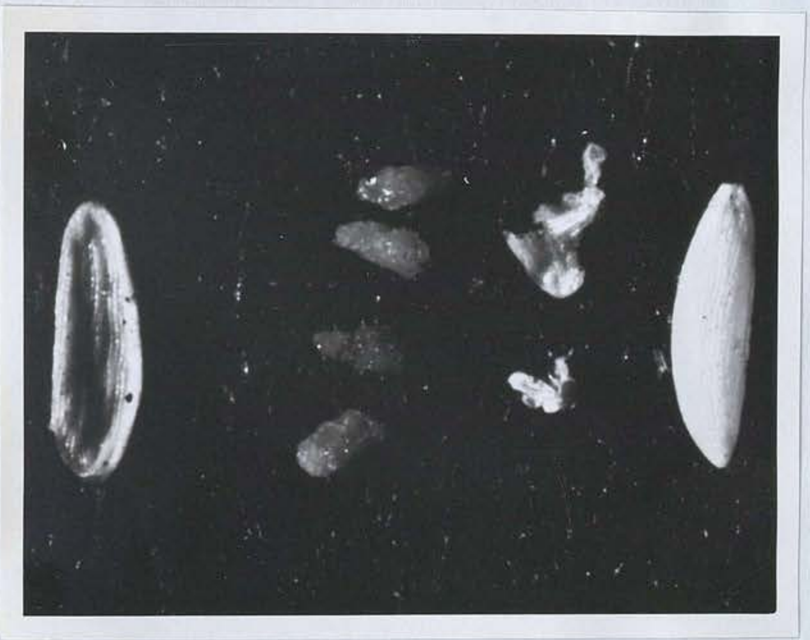


Plate 7. Root fly eggs destroyed by B. guttula X 35.

Plate 8. Root fly eggs destroyed by A. gregaria x35

Plate 9. Root fly eggs destroyed by O. rugosus x35.

number of viable eggs were recorded.

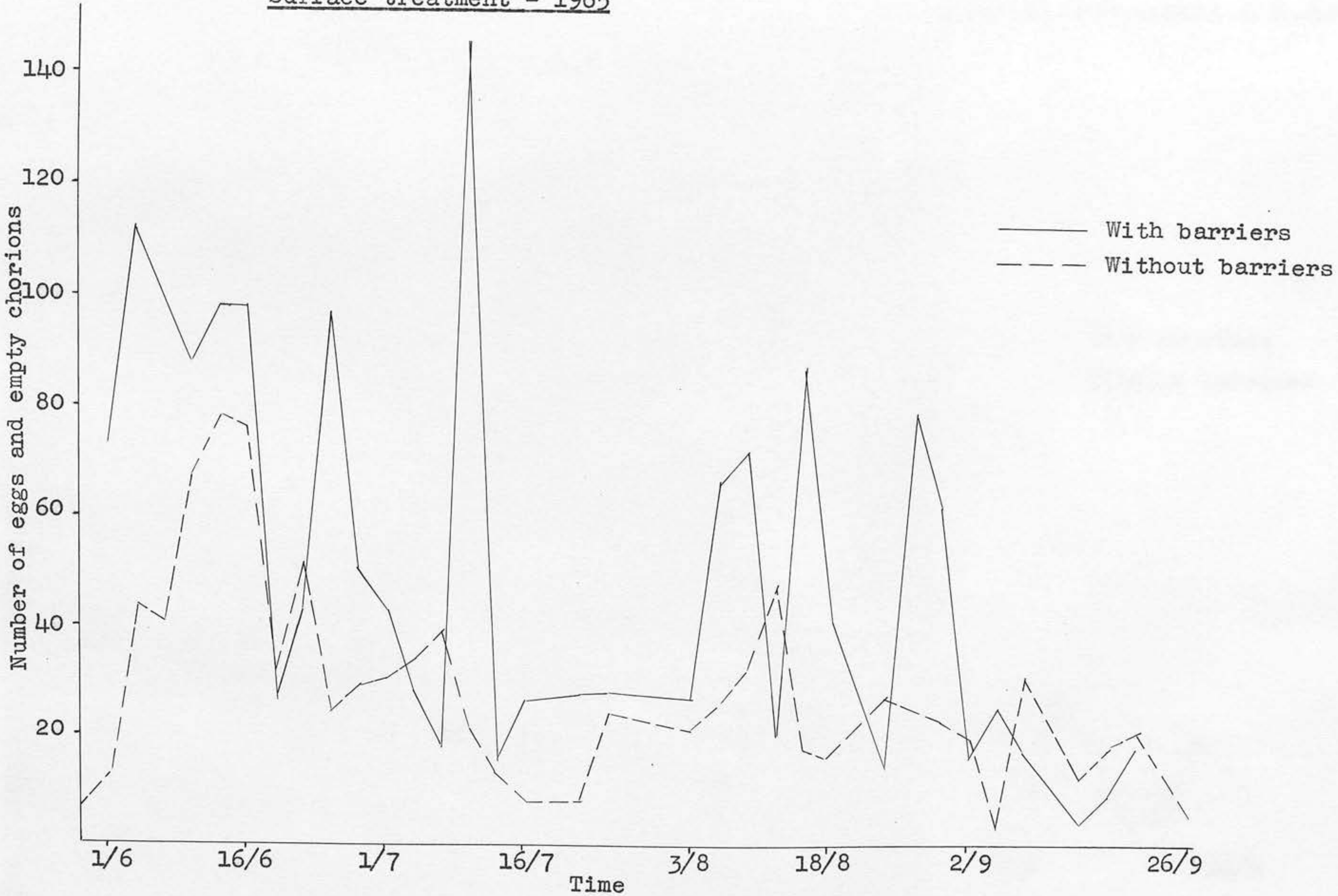
Figures 23, 24 and 25 show the total number of eggs and chorions, sampled every three days, in the surface, the sub-surface diazinon treatments and the controls from plants protected and not protected by barriers in each case. It can be seen from the figures that there were nearly always more cabbage root fly eggs and chorions sampled from plants with barriers, than plants without barriers.

The number of eggs sampled from June 1 till July 25 from each insecticidal treatment, with and without barriers were summed and the mean number of eggs per plot are shown in Table 15, in which records of the unhatched + hatched, the unhatched eggs alone, and the viable eggs were analyzed separately. (Subsequently unhatched eggs are referred to as "full eggs" and hatched eggs as chorions). It is evident from the table that in each case there were more eggs sampled from plants with barriers than from plants without barriers. These differences were significant (P = 0·05) in the sub-surface treatment in the three cases. The totals of the three treatments put together were significantly higher (P = 0·01) in the samples taken from plants with barriers compared with those without barriers.

The per cent reduction in the number of eggs due to the reduction in predation by the barriers in the two treatments and the control is shown in Table 16. The low per cent predation in the control plots shown in the table was unexpected. This, however, could partly be due to the increase in the number of the smaller types of staphylinid which were found to be able to surmount the barriers. This could also have been due to chance, as there was

Fig. 23 Eggs and empty chorions sampled from plants with and without barriers

Surface treatment - 1965



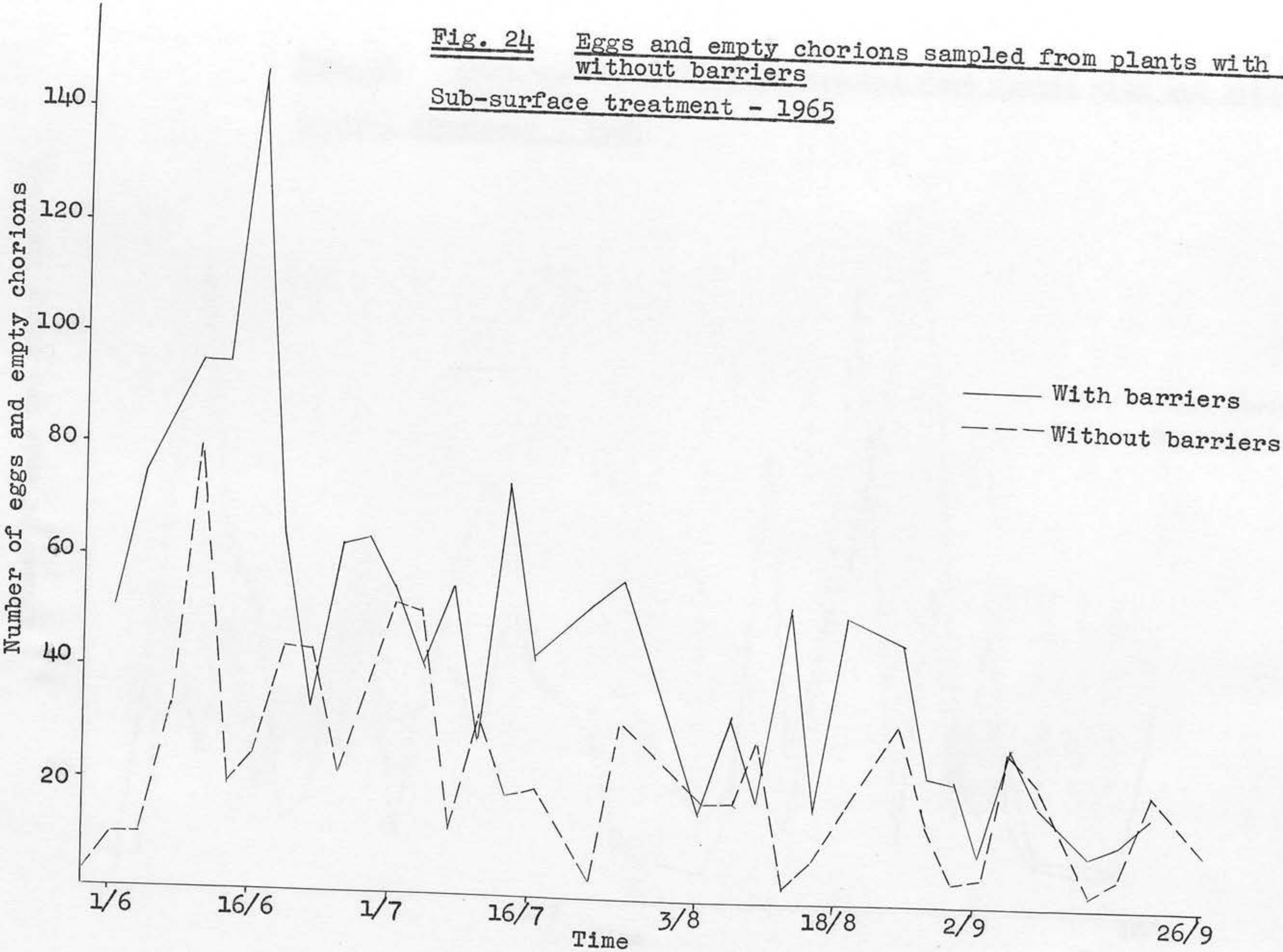


Fig. 24 Eggs and empty chorions sampled from plants with and without barriers

Sub-surface treatment - 1965

Fig. 25 Eggs and empty chorions sampled from plants with and without barriers

Control treatment - 1965.

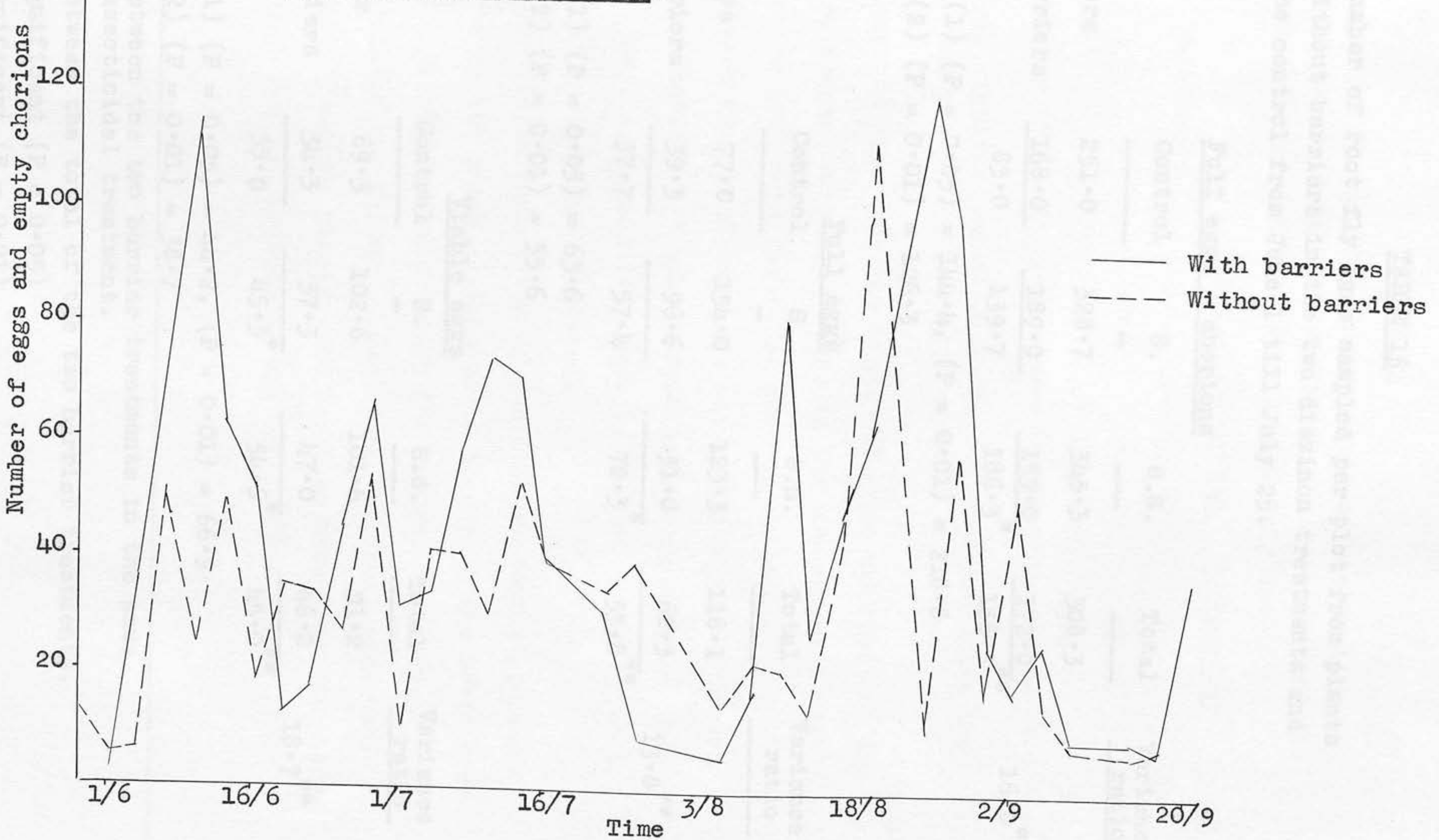


TABLE 15

The mean number of root fly eggs sampled per plot from plants with and without barriers in the two diazinon treatments and the control from June 1 till July 25.

Full eggs + chorions

	Control	S.	S.S.	Total	Variance ratio
With barriers	251·0	328·7	345·3	308·3	
Without barriers	168·0	189·0	159·0	172·0	16·0**
Difference	83·0	139·7	186·3*	136·3**	

L.S.D. (1) (P = 0·05) = 144·4, (P = 0·01) = 218·8
(2) (P = 0·01) = 126·3

Full eggs

	Control	S.	S.S.	Total	Variance ratio
With barriers	77·0	154·0	123·3	118·1	
Without barriers	39·3	96·6	51·0	62·3	13·8**
Difference	37·7	57·4	72·3*	55·8**	

L.S.D. (1) (P = 0·05) = 63·6
(2) (P = 0·01) = 55·6

Viable eggs

	Control	S.	S.S.	Total	Variance ratio
With barriers	69·3	102·6	101·6	91·2	
Without barriers	34·3	57·3	47·0	46·2	18·7**
Difference	35·0	45·3*	54·6*	45·0**	

L.S.D. (1) (P = 0·05) = 44·2, (P = 0·01) = 66·9
(2) (P = 0·01) = 38·7

L.S.D. (1) between the two barrier treatments in the same insecticidal treatment.
(2) between the total of the two barrier treatments.
* significant (P = 0·05)
** significant (P = 0·01)

TABLE 16

Per cent reduction in egg numbers due to greater predation in the absence of barriers in the two diazinon treatments and the control, during the period from June 1 till July 25.

	Control	Surface	Sub-surface	Total
Full eggs + chorions	33	42	54	44
Full eggs	49	37	59	47
Viable eggs	50	44	54	49

no statistical significance between the two treatments and the control.

These results show that the number of eggs and chorions was reduced by an average of 44 per cent. in the experimental plot in total, due to predatory Carabidae and Staphylinidae. The results also show that predation was not significantly affected by the diazinon surface and sub-surface treatments despite the fact that the beetles populations have been shown to be reduced, particularly by the surface treatment.

During the second generation of the cabbage root fly, fewer eggs were laid in the plots. This could be due to the preference of the adult flies to lay eggs around the younger turnip plants in the field adjoining the plots. There were more full eggs and chorions sampled from the plants with barriers than from the plants without, in both the two treatments and the control (Table 17).

TABLE 17

The mean number of eggs sampled per plot from plants with and without barriers and the per cent. reduction due to predation in the two diazinon treatments and the control from August 3 till September 20.

Full eggs + chorions

	Control	S.	S.S.	Total
With barriers	199·3	185·0	124·0	169·4
Without barriers	149·3	137·3	80·0	122·2
% Reduction	25	26	35	28

Full eggs

	Control	S.	S.S.	Total
With barriers	36·0	65·3	16·6	39·4
Without barriers	30·6	29·3	17·0	25·6
% Reduction	15	55	-	35

Viable eggs

	Control	S.	S.S.	Total
With barriers	25·0	61·3	13·0	33·1
Without barriers	22·3	22·0	14·6	19·6
% Reduction	11	64	-	41

B - The 1966 experiment:

The same technique was used to study the predation by Carabidae and Staphylinidae on the egg stage of the cabbage root fly in the two chlorfenvinphos treatments and the control. The number of samples was increased to two egg samples taken from plants with barriers and two from plants without barriers per plot, instead of one of each in the 1965 experiment. Sampling was started on June 26 and continued till August 26.

Figures 26, 27 and 28 show the total number of eggs and chorions in the samples taken every three days throughout the season from plants with and without barriers, in the surface, the sub-surface and the control treatments. The mean number of eggs sampled from May 26 till July 16 from plants with and without barriers per plot is shown in Table 18. It is shown in the table that the number of eggs + chorions in the samples from plants without barriers was significantly lower than those taken from plants with barriers, the differences being highest in the sub-surface treatment (significant at 1% level), followed by the control, then the surface treatment (both significant at 5% level). The difference between the totals of the three treatments together was significant at 1% level calculated for the full eggs + chorions and the full eggs alone, and was significant at 5% level for the viable eggs.

As in 1965 there was no statistical significance between the mean number of eggs sampled from each of the two insecticide treatments and the control, and the interactions between the insecticidal treatments and the barrier treatments were also non-significant.

The per cent. reduction in egg numbers due to predation during the root fly first generation is shown in Table 19. The low predation in the surface treatment could be due to the mortality of a considerable number of the Staphylinidae. The unexpected lower predation which occurred in the control plots might be attributable, as in 1965, to the higher population of Staphylinidae

Fig. 26 Eggs and empty chorions sampled from plants with and without barriers

Surface treatment - 1966

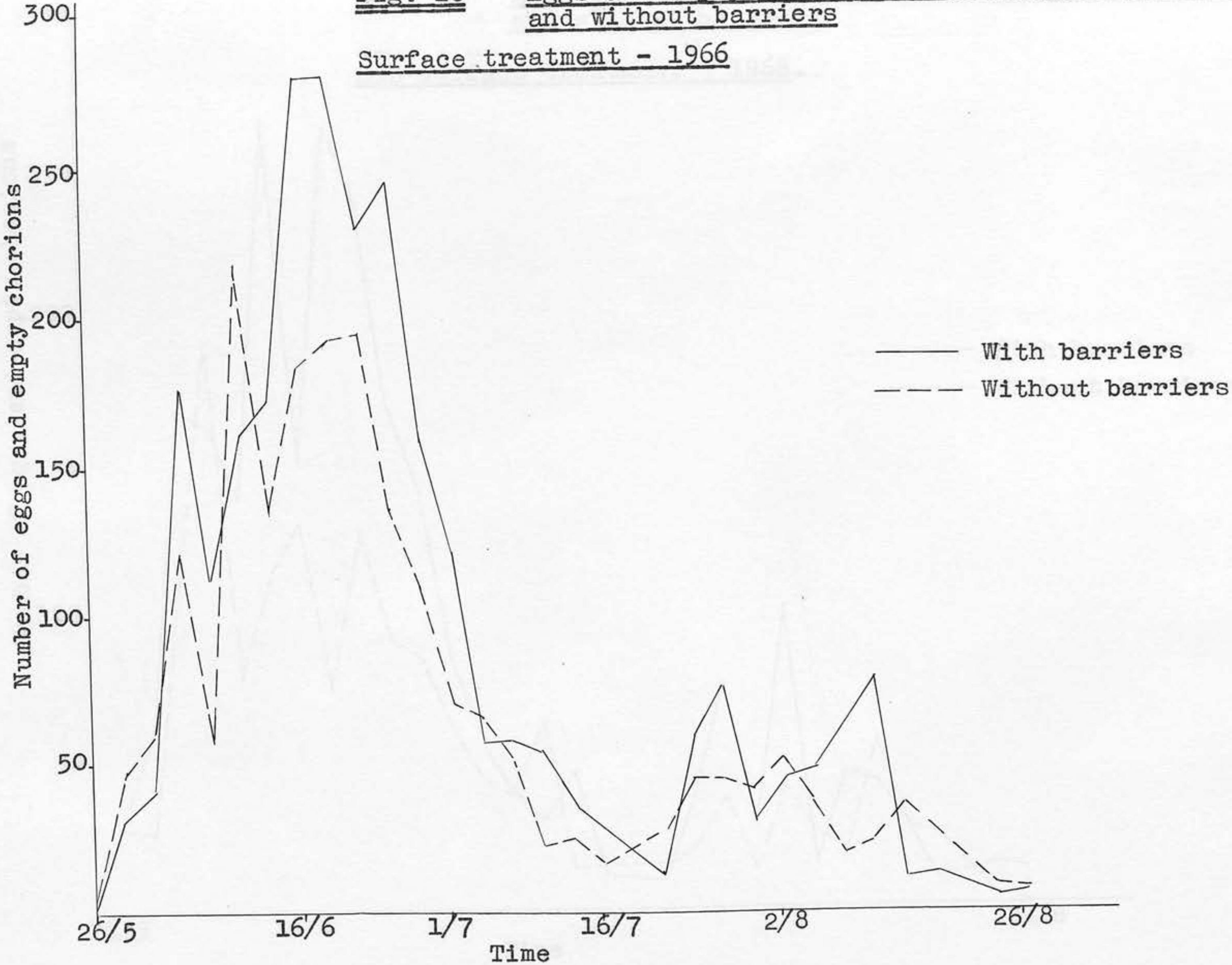
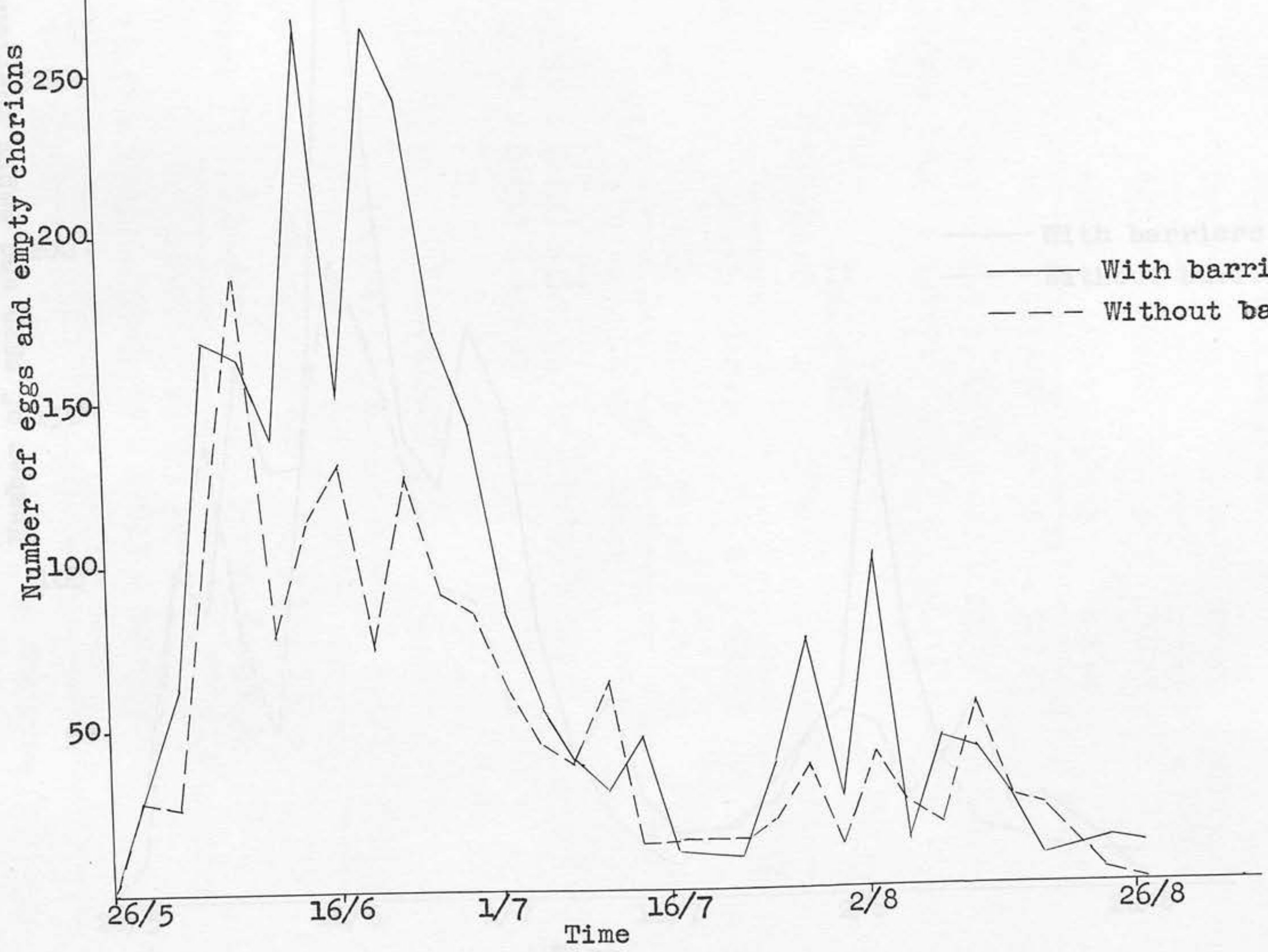


Fig. 27 Eggs and empty chorions sampled from plants with and without barriers.

Sub-surface treatment - 1966.



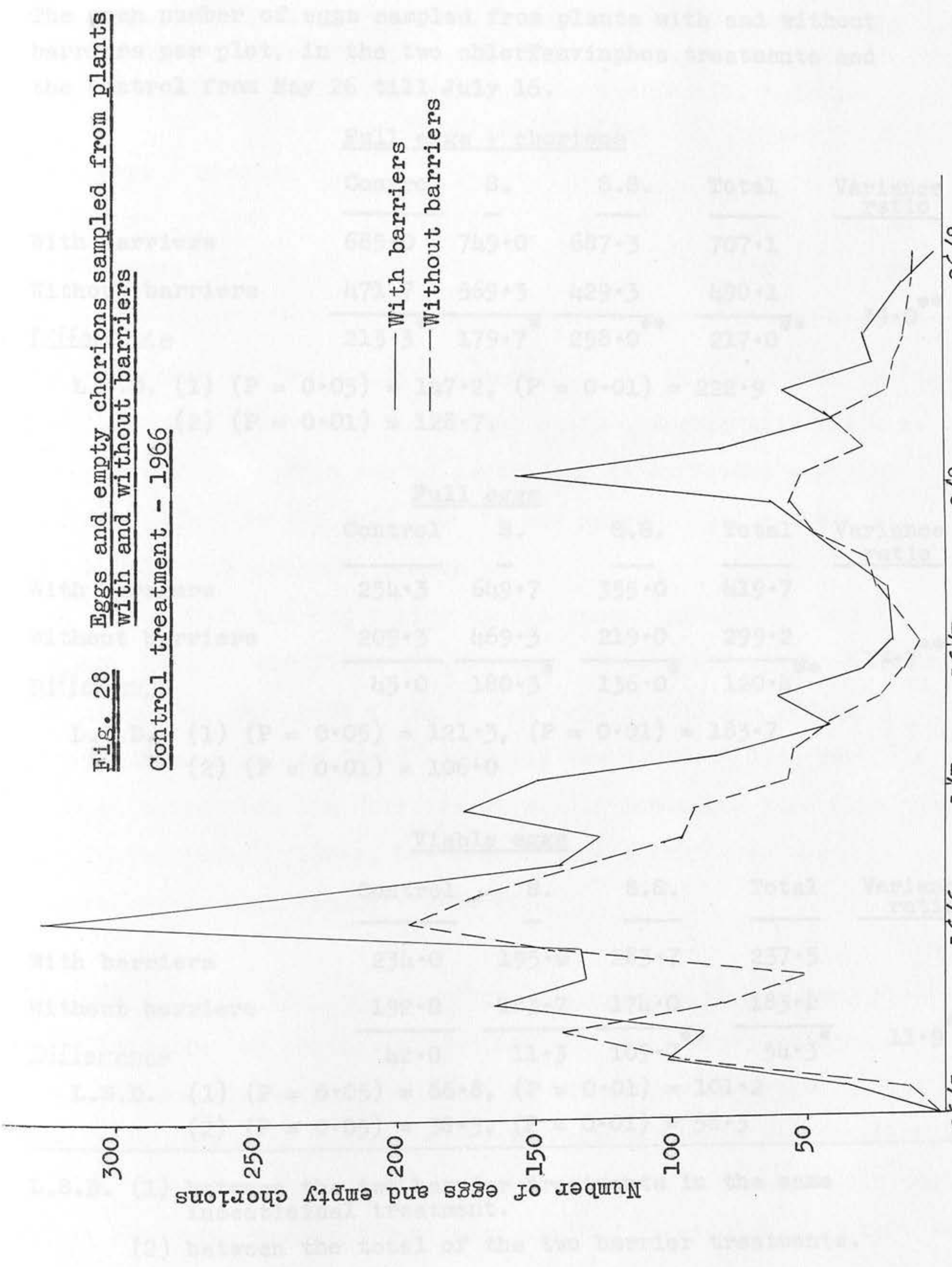


Fig. 28 Eggs and empty chorions sampled from plants with and without barriers

Control treatment - 1966

TABLE 18

The mean number of eggs sampled from plants with and without barriers per plot, in the two chlorfenvinphos treatments and the control from May 26 till July 16.

Full eggs + chorions

	Control	S.	S.S.	Total	Variance ratio
With barriers	685·0	749·0	687·3	707·1	
Without barriers	471·7	569·3	429·3	490·1	
Difference	213·3*	179·7*	258·0**	217·0**	39·0**

L.S.D. (1) (P = 0·05) = 147·2, (P = 0·01) = 222·9
(2) (P = 0·01) = 128·7.

Full eggs

	Control	S.	S.S.	Total	Variance ratio
With barriers	254·3	649·7	355·0	419·7	
Without barriers	209·3	469·3	219·0	299·2	
Difference	45·0	180·3*	136·0*	120·4**	17·7**

L.S.D. (1) (P = 0·05) = 121·3, (P = 0·01) = 183·7
(2) (P = 0·01) = 106·0

Viable eggs

	Control	S.	S.S.	Total	Variance ratio
With barriers	234·0	195·0	283·7	237·5	
Without barriers	192·0	183·7	174·0	183·2	
Difference	42·0	11·3	109·7**	54·3*	11·9*

L.S.D. (1) (P = 0·05) = 66·8, (P = 0·01) = 101·2
(2) (P = 0·05) = 38·5, (P = 0·01) = 58·3

L.S.D. (1) between the two barrier treatments in the same insecticidal treatment.
(2) between the total of the two barrier treatments.

* Significant (P = 0·05)

** Significant (P = 0·01)

TABLE 19

Per cent. reduction in egg numbers due to greater predation in the absence of barriers in the two chlorfenvinphos treatments and the control, during the period from May 26 till July 16.

	Control	Surface	Sub-surface	Total
Full eggs + chorion	31	24	37	31
Full eggs	18	28	38	29
Viable eggs	18	6	39	23

compared with the two other treatments. It is shown from the table that less predation occurred in the plots compared with the same period of 1965. This can be partly due to different seasonal effects. But as the 1966 results are based on twice the number of samples they are more reliable.

As in 1965 the egg laying by the second generation was less intense than by the first generation. This could be due to the preference of the adult flies to lay eggs around the younger rad~~d~~ish plants in the field adjoining the plots. Once more the samples taken from the "barriered" plants contained more eggs than the "unbarriered" plants, but none of the differences was statistically significant (Table 20).

The reduction in the larval and pupal stages due to egg predation:

Predation by beetles on the egg and small larval stages of the fly, and the consequent reduction in the number of mature larvae and pupae infesting the roots of the cabbage plants was examined in 1966. Barriers (3 per insecticidal treatment plot and 6 per control plot) were placed around randomly selected plants and were kept in

TABLE 20

The mean number of eggs sampled per plot from plants with and without barriers and the per cent. reduction due to predation in the two chlorfenvinphos treatments and the control from July 21 till August 26

Full eggs + chorions

	Control	S.	S.S.	Total
With barriers	188·3	149·3	137·3	158·3
Without barriers	116·0	123·0	93·3	110·8
% reduction	38·4	17·6	32·0	30·0

Full eggs

	Control	S.	S.S.	Total
With barriers	60·0	52·7	42·7	51·8
Without barriers	33·3	47·7	33·0	38·0
% reduction	44·4	9·5	22·7	26·6

Viable eggs

	Control	S.	S.S.	Total
With barriers	55·0	37·3	40·3	44·2
Without barriers	31·3	35·7	30·0	32·3
% reduction	43·0	4·5	25·6	26·9

position during the two egg laying periods of the first and the second cabbage root fly generations. This technique has previously been described. The plants within the barriers and a similar number of plants without barriers were examined for larvae and pupae. Table 21 shows the number of larvae and pupae from plants with and without barriers at the end of each of the first and second cabbage root fly generations and the damage caused to the roots.

TABLE 21

Period	With barriers						No barriers					
	Larvae of instars			Pup-ae	Total L + P	Root Dam-age	Larvae of instars			Pup-ae	Total L + P	Root Dam-age
	1	2	3				1	2	3			
12/7 - 18/7	0	12	44	49	105	45	0	5	35	22	62	27
30/8 - 7/9	0	16	11	15	42	15	0	0	5	16	21	14

It is shown in the table that more larvae, pupae and more damage to the roots occurred in the plants with the barriers. The differences are, however, non-significant. As no larvae or pupae were found in the samples taken from the chlorfenvinphos treated plots, they were not included in the table.

Predation by the larger Carabidae on the cabbage root fly larvae and pupae:

Some of the larger Carabidae are known to feed on the larval and pupal stages of the cabbage root fly. Wright (1956) mentioned that in the laboratory one individual of Pterostichus spp. consumed 180 pupae and 23 third instar larvae of the cabbage root fly over a six month period.

In the present investigation P. madidus was observed in the laboratory to feed very rapidly on larvae and pupae when enclosed in a petri dish. Plate 10 shows a P. madidus feeding on a cabbage root fly pupa.

The root fly larvae and pupae in the field are normally present at a depth of ½ to 6 inches. An attempt was made to find out

Plate 10. P. madidus feeding on a root fly pupa x 3.

whether P. madidus would feed on the larvae and pupae at the depth of ½ to 1 inch under the surface of the soil. 10 jam jars were filled with soil to the middle with one well grown cabbage root fly larva and one pupa placed at a depth of ½ to 1 inch. The jars were checked one week later. All the larvae had developed into pupae except two which had been eaten. Further examination showed that only one pupa had been eaten during the third week of the experiment. A similar trial with N. brevicollis was carried out with pupae only (2 per jar) and only one pupa was eaten. This result indicates that predation by the Carabidae on the larval and pupal stages of the cabbage root fly plays a very minor role in reducing the pest population in the field.

III. Parasitism by I. rapae and A. bilineata:

Cabbage root fly larvae and pupae collected from soil samples taken in the field were examined for parasites. The pupae were examined on wet filter paper in petri dishes under a binocular microscope. Pupae parasitised by I. rapae were readily identified as they were significantly ($P = 0{\cdot}01$) smaller in size than the normal pupae (see Table 22), with dark irregular blotches visible through the posterior end of the puparium. In most cases the parasite larvae (usually in the fourth-instar) could be seen through the puparium. The pupae parasitised by A. bilineata did not differ in size from the normal unparasitised ones (Table 22). In most cases moisture makes the puparium semi-transparent, and by using a strong light, the puparia which contain parasites may be detected with comparative ease. The small Staphylinid larva and the circular entrance made by it, usually white or dark brown in colour, could be seen on the surface of the puparium (Wadsworth, 1915). Plate 11 shows an A. bilineata parasitic larva within the cabbage root fly puparium. The anterior part of the puparium was removed to show the parasite.

After examination the larvae and pupae were reared in the laboratory and the emergence of the adult parasites was recorded. Cabbage root fly pupae were first collected from a turnip crop grown during the summer of 1964 at Seafield. The crop was harvested on January 5, 1965. Moderate damage caused by the fly was observed on the roots. Out of 144 pupae collected from that crop 74 (51%) were parasitised by I. rapae, and 19 (13%) were parasitised by A. bilineata.

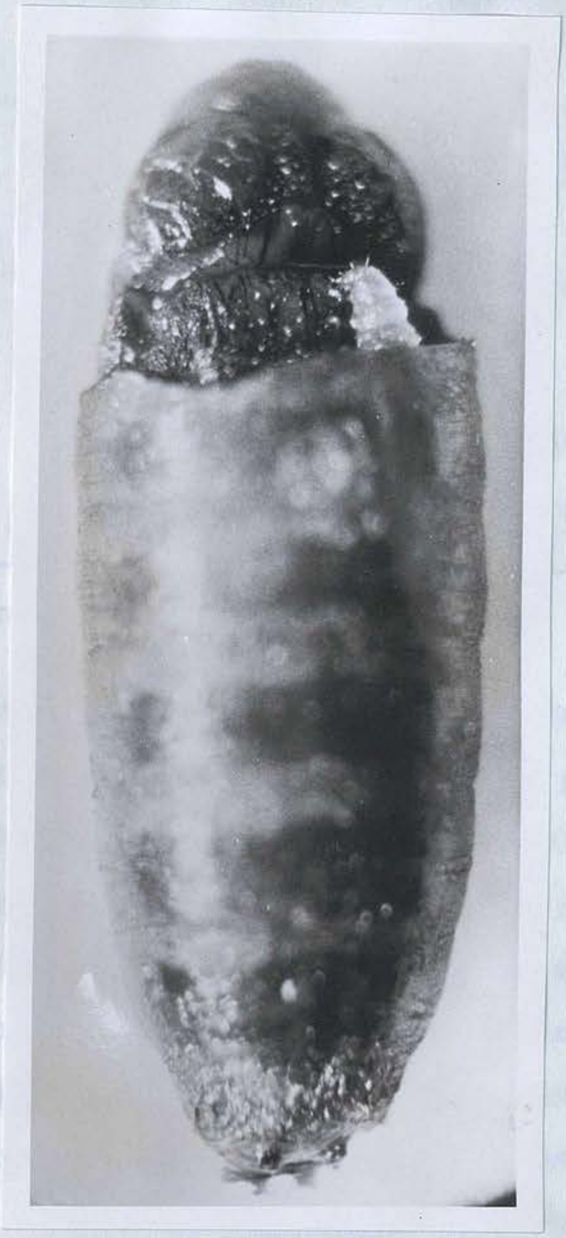


Plate 11. A. bilineata parasitic larva within a root fly puparium X 23.

TABLE 22

Measurements of root fly pupae parasitised by I. rapae, A. bilineata and normal pupae.

Root fly pupae	No. of pupae	Mean length	Value of t.	Mean greatest width	Value of t.
Normal	109	6·01		2·30	
Parasitised by:					
I. rapae	92	5·12**	13·4	1·94**	14·1
A. bilineata	18	5·96	0·34	2·19	0·07

** Significant (P = 0·01)

During 1965 only 4 pupae out of 46 belonging to the first root fly generation from the control plots were parasitised by I. rapae. The diazinon treated plots were completely free from root fly larvae and pupae. During the second generation 29 (19%) pupae parasitised by I. rapae were recorded out of the 155 pupae collected from both the treated and untreated plots. No parasitisation by A. bilineata was recorded during the whole season.

In adult emergence cages placed above areas where turnips were harvested in 1965, a total of 8 I. rapae (19%) were captured with 34 cabbage root fly adults emerging during May 1966. Among the pupae produced by the first generation flies 1966, out of 177 collected in the field, 23 (13%) were parasitised by I. rapae and 2 by A. bilineata.

Among the adults of the second generation emerging during

July 1966, 7 I. rapae adults (14%) were captured in the cages together with 43 cabbage root fly adults. 22 (17%) out of the 131 pupae produced by the second generation flies in the field were parasitised by I. rapae. The chlorfenvinphos treated plots were completely free from root fly throughout the whole season. The remarkable reduction in parasitism which occurred in 1965 and 1966 compared with 1964 may be due to the use of insecticides.

IV. The control of the cabbage root fly by diazinon and chlorfenvinphos:

a) Ovicidal effect:

Both the diazinon and chlorfenvinphos had some ovicidal effect on the cabbage root fly when applied on the surface. Egg viability was examined in the surface, the sub-surface insecticidal treatments and the control throughout the two seasons. Eggs from field samples were kept for a period of six days, the number of eggs hatching was then recorded. Figure 29 shows the number of full eggs from the two diazinon treatments and the control throughout the 1965 experiment together with the number of hatched eggs. Figures 30 and 31 show the same for the chlorfenvinphos treatments during 1966. The surface treatments of each of the two insecticides are shown to have a significant ovicidal effect but not the sub-surface treatments.

The viability of cabbage root fly eggs sampled from each treatment during the first and second root fly generations of 1965 and 1966 are shown in Table 23. It is clear from the table and the figures that chlorfenvinphos had a much greater ovicidal effect than the diazinon. The effect of the chlorfenvinphos is also seen to last for a longer time. The reduction in egg viability in the diazinon surface treatment is shown to be significant at 1% level compared with the control, and significant at 5% level compared with the sub-surface treatment. The chlorfenvinphos applied on the surface had significantly reduced egg viability at 1% level compared with both the control and the sub-surface treatment. Egg viability was not significantly affected by the sub-

Fig. 29 **Egg viability - 1965**

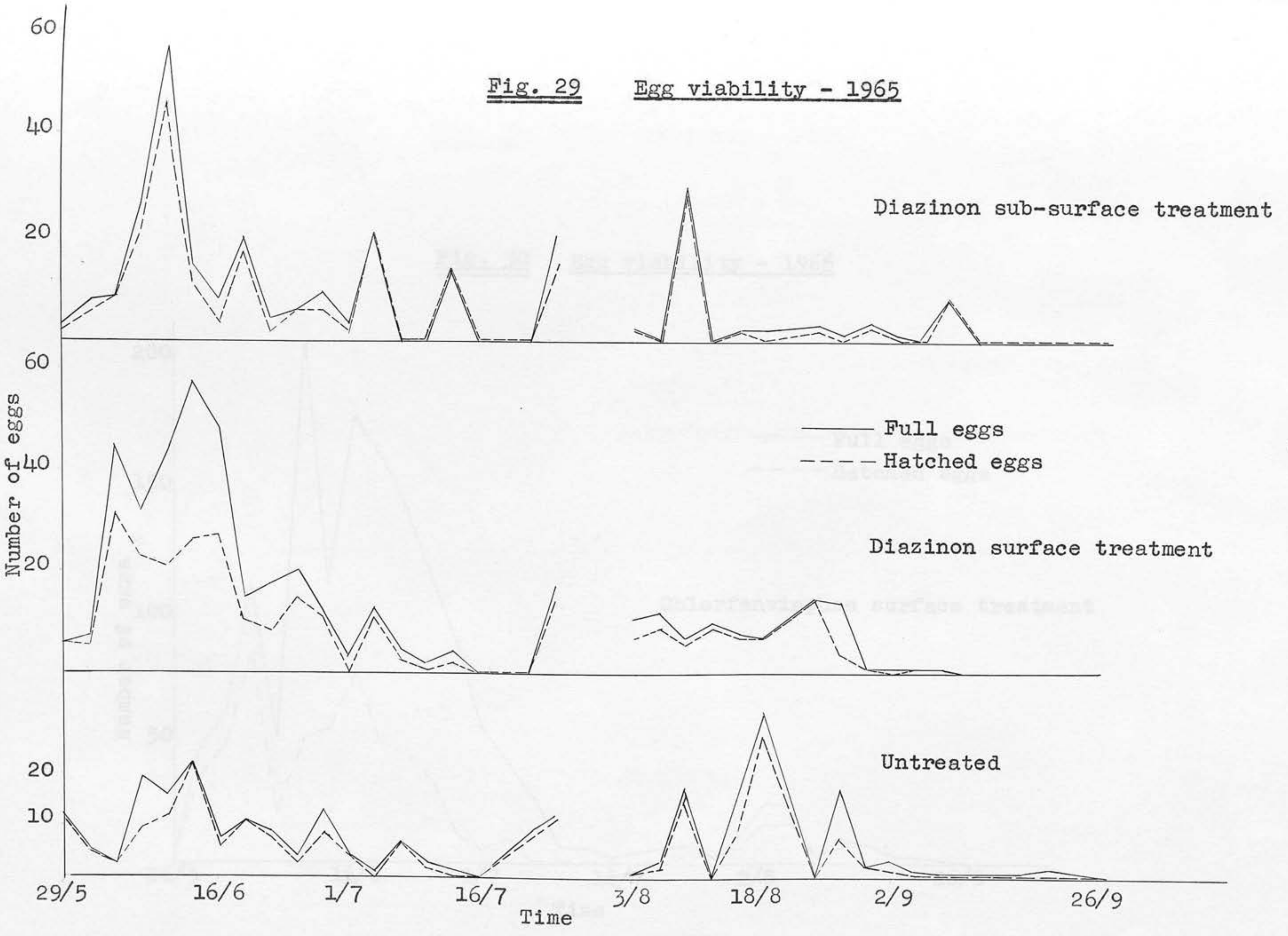


Fig. 30 **Egg viability - 1966**

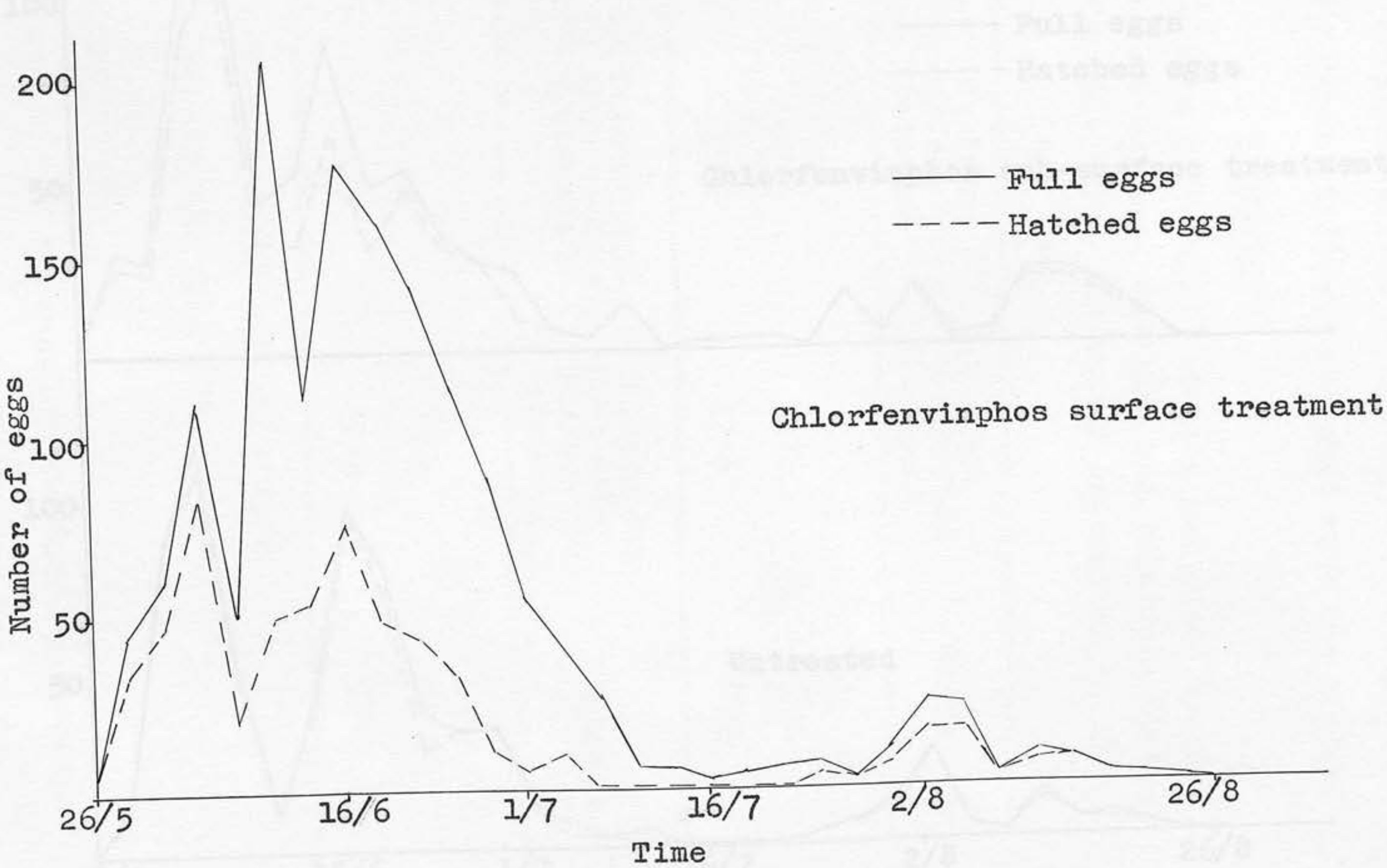
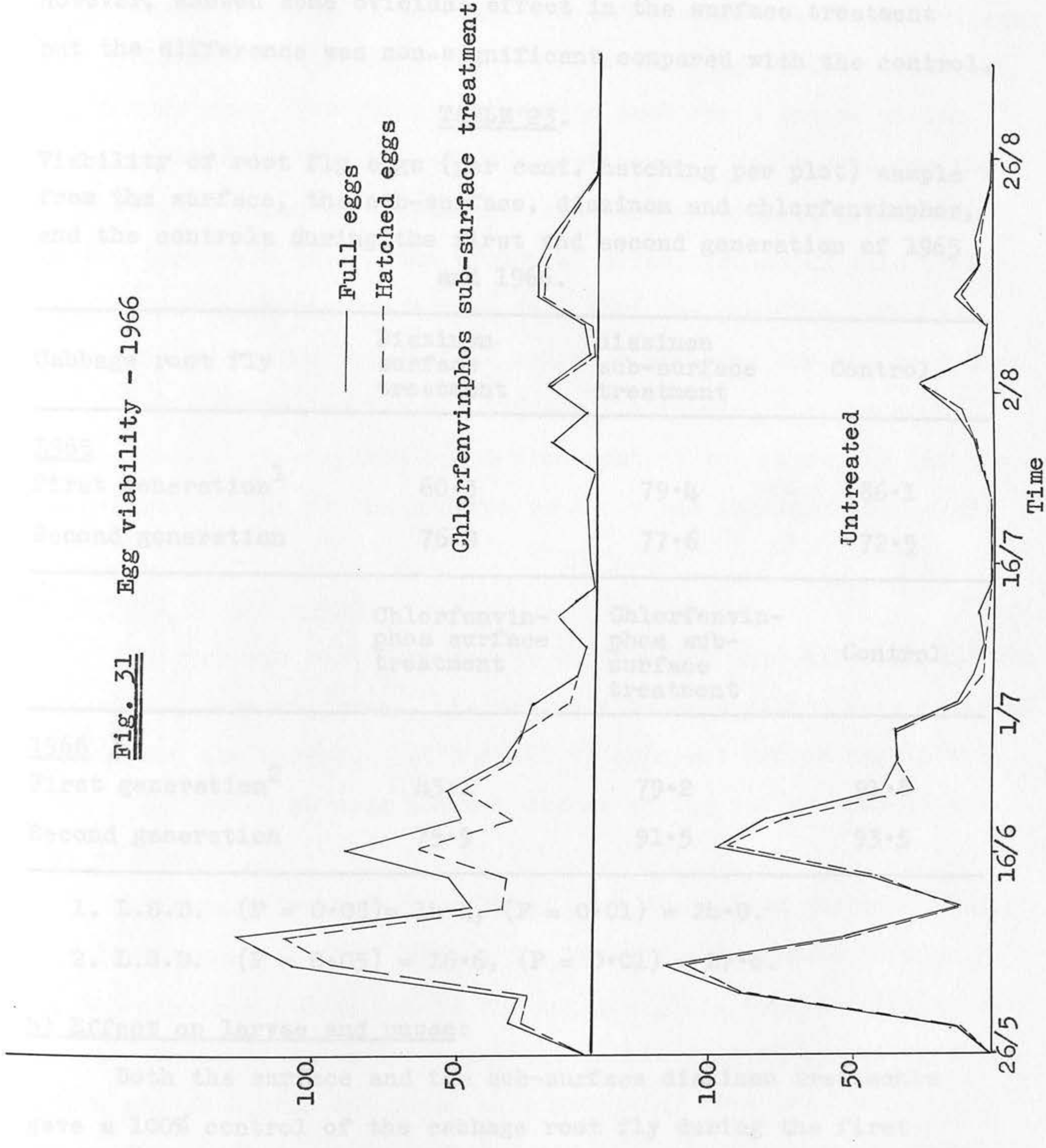


Fig. 31 Egg viability - 1966



surface diazinon and chlorfenvinphos treatments.

During the second generation of the cabbage root fly the diazinon had no effect on egg viability. The chlorfenvinphos, however, showed some ovicidal effect in the surface treatment but the difference was non-significant compared with the control.

TABLE 23.

Viability of root fly eggs (per cent. hatching per plot) sample from the surface, the sub-surface, diazinon and chlorfenvinphos, and the controls during the first and second generation of 1965 and 1966.

Cabbage root fly	Diazinon surface treatment	diazinon sub-surface treatment	Control
1965			
First generation[1]	60·3	79·4	86·1
Second generation	76·9	77·6	72·5
	Chlorfenvinphos surface treatment	Chlorfenvinphos sub-surface treatment	Control
1966			
First generation[2]	43·1	79·2	91·8
Second generation	75·9	91·5	93·5

1. L.S.D. (P = 0·05) = 14·4, (P = 0·01) = 24·0.
2. L.S.D. (P = 0·05) = 16·6, (P = 0·01) = 27·6.

b) Effect on larvae and pupae:

Both the surface and the sub-surface diazinon treatments gave a 100% control of the cabbage root fly during the first generation. It is shown in Table 24 that no larvae or pupae were found in the treated plots till July 20. During the second generation, starting at the beginning of August, the diazinon applied on the surface was not effective against the pest. It was interesting to see that although the sub-surface diazinon treatment was applied in the field 5 days earlier than the surface treatment, the former gave protection against the pest for a longer period of time compared with the surface treatment. Table 24 shows that no larvae or pupae were obtained from the sub-surface treatment before September 18. The prolonged effectiveness of this treatment could be partly due to the fact that the granules were less disturbed by weather conditions compared with the surface treatment.

The chlorfenvinphos was extremely effective for the control of the pest. A complete protection against the first and the second generation of the cabbage root fly was obtained (Table 25).

c) Effect on the crops:

The cabbage root fly attacks during 1965 were mild and did not markedly affect the crop. No severely damaged plants were recorded throughout the season. At harvest no apparent difference in the crop yield could be seen between either of the two treatments and the control.

A comparatively heavy cabbage root fly attack occurred during the first generation of 1966, and a considerable amount of damage to the plants was observed in the control plots towards the end of July. Plate 12 shows three cabbage plants damaged by the pest; 17, 6 and 28 larvae and pupae were recovered from the plants shown from left to right respectively. Plate 13 shows four roots severely damaged; 5, 17, 22 and 10 larvae and pupae were extracted

TABLE 24

Cabbage root fly larvae and pupae sampled from the diazinon treatments and the control and the damage caused to the roots at intervals during 1965.

Date	Control					Surface treatment					Sub-surface treatment				
	Larvae of instars			Pupae	Root damage	Larvae of instars			Pupae	Root Damage	Larvae of instars			Pupae	Root Damage
	1	2	3			1	2	3			1	2	3		
18/6/65	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5/7	0	3	6	2	4	0	0	0	0	0	0	0	0	0	0
20/7	1	7	6	8	8	0	0	0	0	0	0	0	0	0	0
21/8	4	2	8	5	7	9	4	4	1	2	0	0	0	0	0
18/9	0	6	4	13	6	0	3	16	3	5	0	0	21	3	5
5/10	0	0	8	8	5	0	0	12	14	5	0	0	3	8	4
11/10	0	0	2	14	7	0	0	0	18	5	0	0	0	14	6
19/10	0	0	0	16	5	0	0	0	31	7	0	0	0	7	2

TABLE 25

Cabbage root fly larvae and pupae sampled from the chlorfenvinphos treatments and the control and the damage caused to the roots at intervals during 1966.

Date	Control					Surface treatment					Sub-surface treatment				
	Larvae of instars			Pupae	Root damage	Larvae of instars			Pupae	Root damage	Larvae of instars			Pupae	Root damage
	1	2	3			1	2	3			1	2	3		
18/6/66	7	36	18	0	9	0	0	0	0	0	0	0	0	0	0
24/6	0	10	33	3	15	0	0	0	0	0	0	0	0	0	0
12/7	0	3	11	4	11	0	0	0	0	0	0	0	0	0	0
18/7	0	2	24	18	16	0	0	0	0	0	0	0	0	0	0
30/8	0	0	4	2	6	0	0	1	0	0	0	0	0	0	0
7/9	0	0	1	14	8	0	0	0	0	0	0	0	0	0	0

Plate 12. Cabbage plants damaged by the cabbage root fly

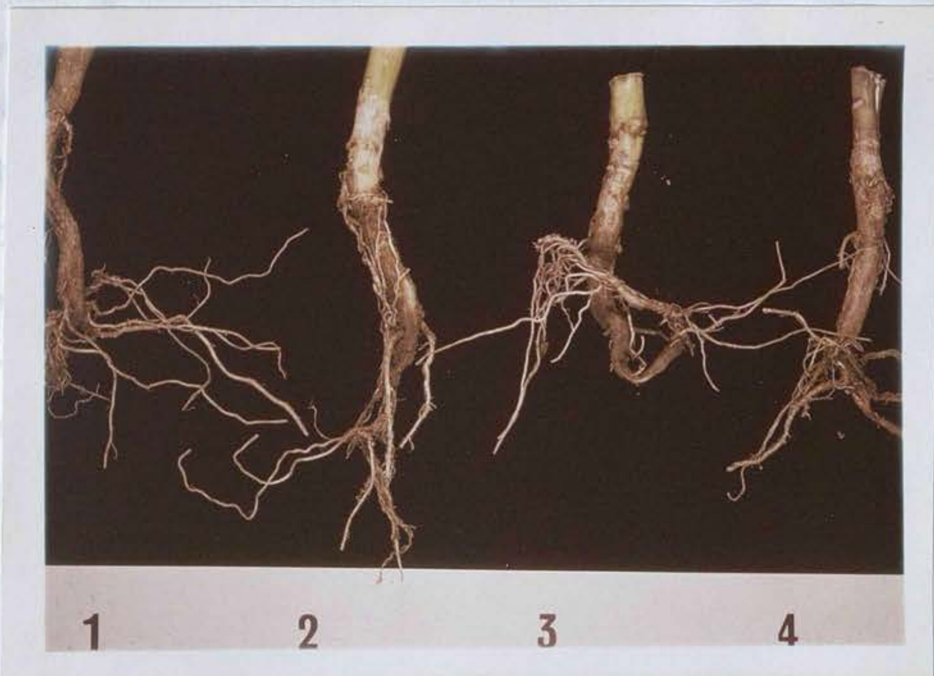


Plate 13. Cabbage roots damaged by the cabbage root fly.

from the roots numbered 1 to 4 respectively. No estimate of the number of plants damaged was made at this stage. Favourable weather during August, however, helped many of the wilting plants to survive. The second generation of the root fly was much less intense compared with the first generation. During this period, plants in the control plots were able to grow and recover from the strong attack of the first generation.

The plants were harvested on September 13. Each plant was cut at ground level, the head was then separated from the lower part of the plant and each was weighed separately. The total plant weight and the mean plant weight in pounds per plot is shown in Table 26. Although more crop was harvested in the treated plots than the control, the differences were statistically non-significant. The difference in mean plant weight per plot was also non-significant. Table 27 shows the number of cabbage heads harvested per plot grouped according to their weights in both the two treatments and the control. More marketable heads (weighing over $\frac{1}{2}$ lb. each) were harvested in the surface and the sub-surface treatments than in the control. There were more plants missing and more small heads (weighing less than $\frac{1}{2}$ lb. each) in the control plots compared with the treated plots. These differences were, however, non-significant. It was noted that the number of large heads weighing over 2 lb. was increased in the control plots compared with the treated plots. These differences are also non-significant.

TABLE 26

Total plant weight harvested and the mean weight per plant in pounds per plot in the two chlorfenvinphos treatments and the control

Treatment	Replicates I	II	III	Mean weight per treatment
Control	119·4 (0·79)	282·4 (1·66)	255·6 (1·49)	219·2 (1·32)
Surface	302·9 (1·64)	314·6 (1·72)	140·7 (0·82)	252·7 (1·39)
Sub-surface	275·8 (1·48)	205·3 (1·14)	235·9 (1·26)	239·0 (1·29)

TABLE 27

Number of cabbage heads harvested per plot grouped according to their weights in the two chlorfenvinphos treatments and the control

Treatment		Missing plants	Head weight of plants: Under $\frac{1}{2}$ lb.	$\frac{1}{2}$ lb.- 1 lb.	1 lb.- 2 lb.	over 2 lb.	Marketable (over $\frac{1}{2}$ lb.)
Control	I	40	109	13	21	7	41
	II	20	60	31	40	39	110
	III	19	72	36	36	27	99
		79	241	80	97	73	250
S.	I	5	46	43	80	16	139
	II	7	28	48	86	21	155
	III	19	112	32	22	5	59
		31	186	123	188	42	353
S.S.	I	4	58	51	57	20	128
	II	11	97	35	37	10	82
	III	3	64	54	58	11	123
		18	219	140	152	41	333

V. Effect of weather on the cabbage root fly.

Meteorological data:

The data were obtained from Bush House weather station situated about half a mile from the experimental site. Figures 32 and 33 show the weekly sunshine and rainfall respectively from May to October. Figures 34 and 35 show the means of maximum, minimum temperature and the mean wind speed in knots respectively every three days from May 20 to October 4.

The effect of temperature on the emergence of adults from overwintering pupae:

In order to advise growers about the time of application of control measures against the cabbage root fly investigations have been carried out by many workers in order to provide reliable methods for the prediction of the time of emergence of the pest flies from the overwintering pupae, and the appearance of the eggs in the field. Schoene (1916), Glasgow (1925), Brittain (1927) have associated the occurrence of the flies and the beginning of egg laying with the time of flowering of certain wild and cultivated plants, i.e. Prunus spp. Miles (1954) suggested that the egg laying by the first generation begins in the first period of warm sunny weather after the middle of April. Coaker and Wright (1963) showed that morphogenesis of the cabbage root fly overwintering pupae is completed at constant temperature after an accumulation of about 368 day degrees above 42°F. The day degrees were calculated in the field by the same authors at Wellesbourne over a period of 11 years. The accumulated total day degrees above 42°F from the

Fig. 32 Total weekly sunshine

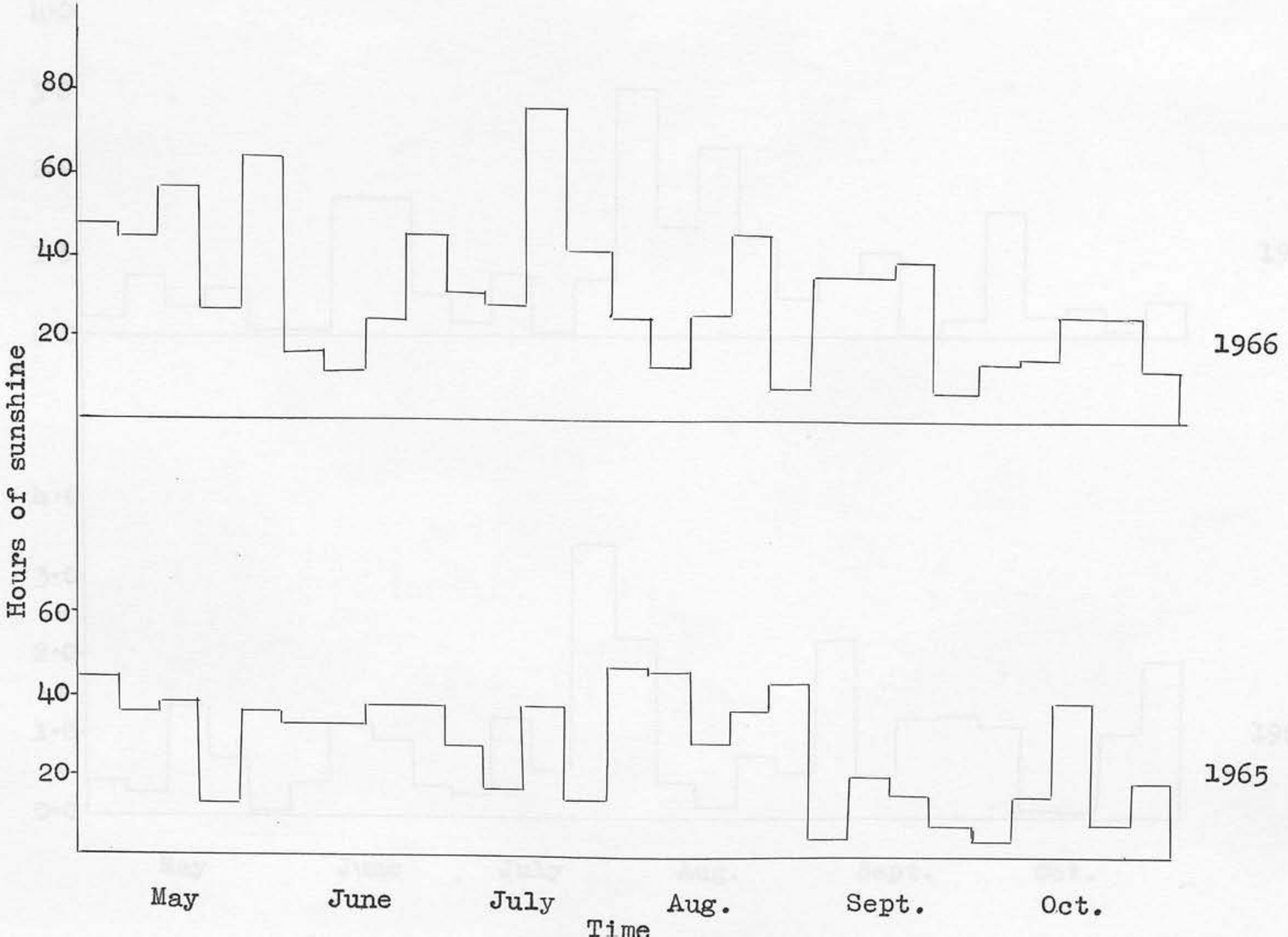


Fig. 33 Rainfall - Weekly totals in inches

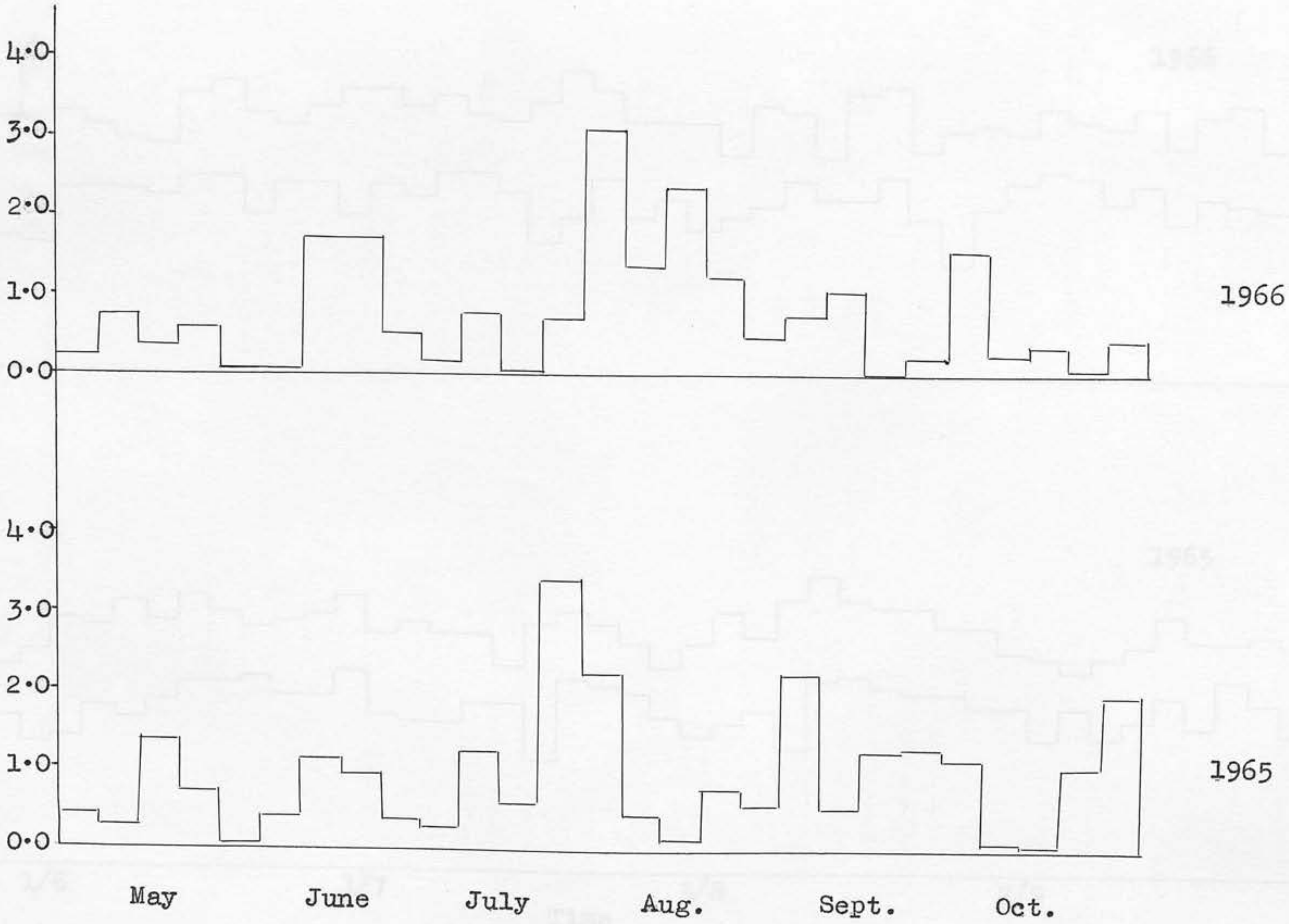
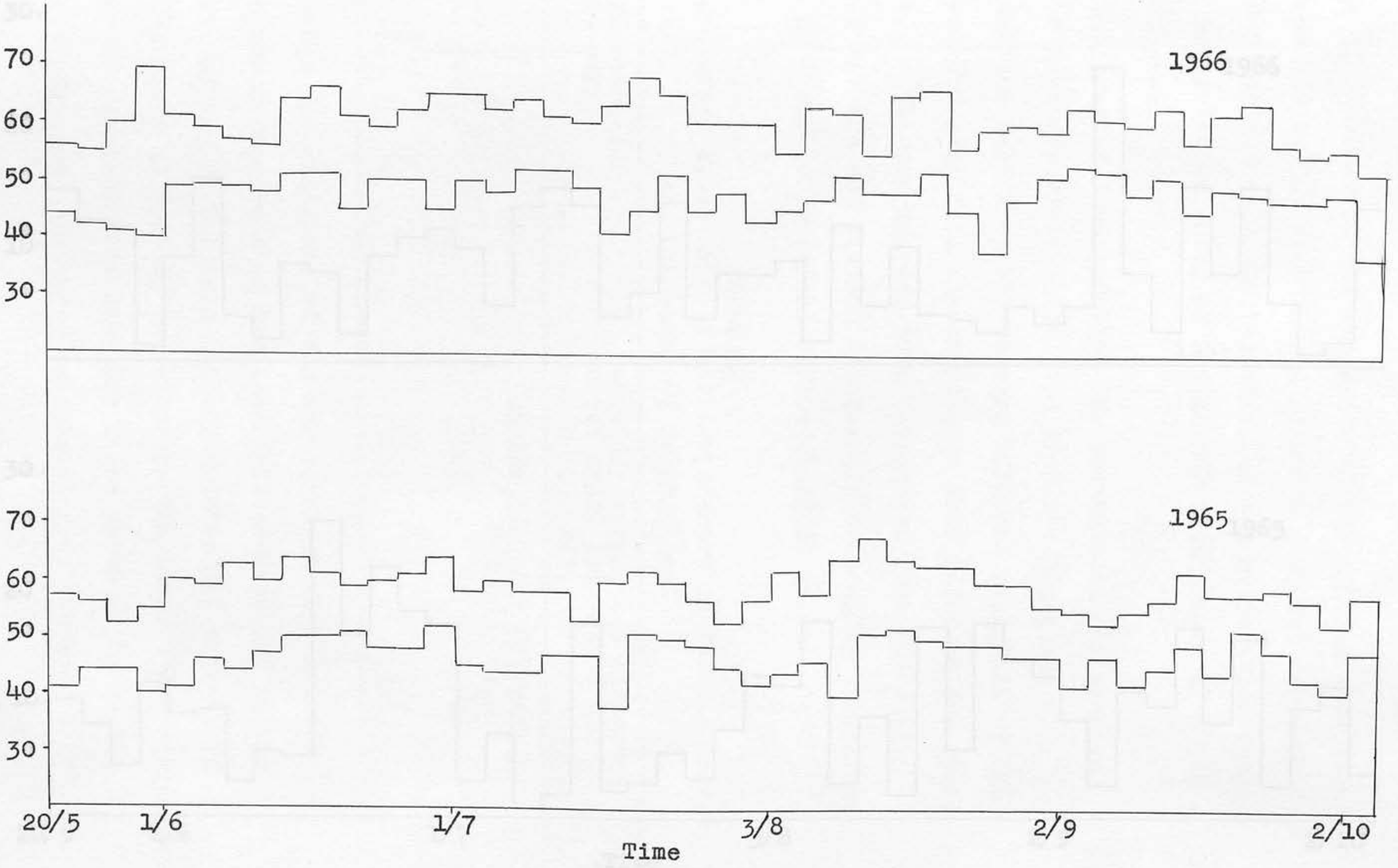


Fig. 34 Mean Max. and Min. temperature over three day periods



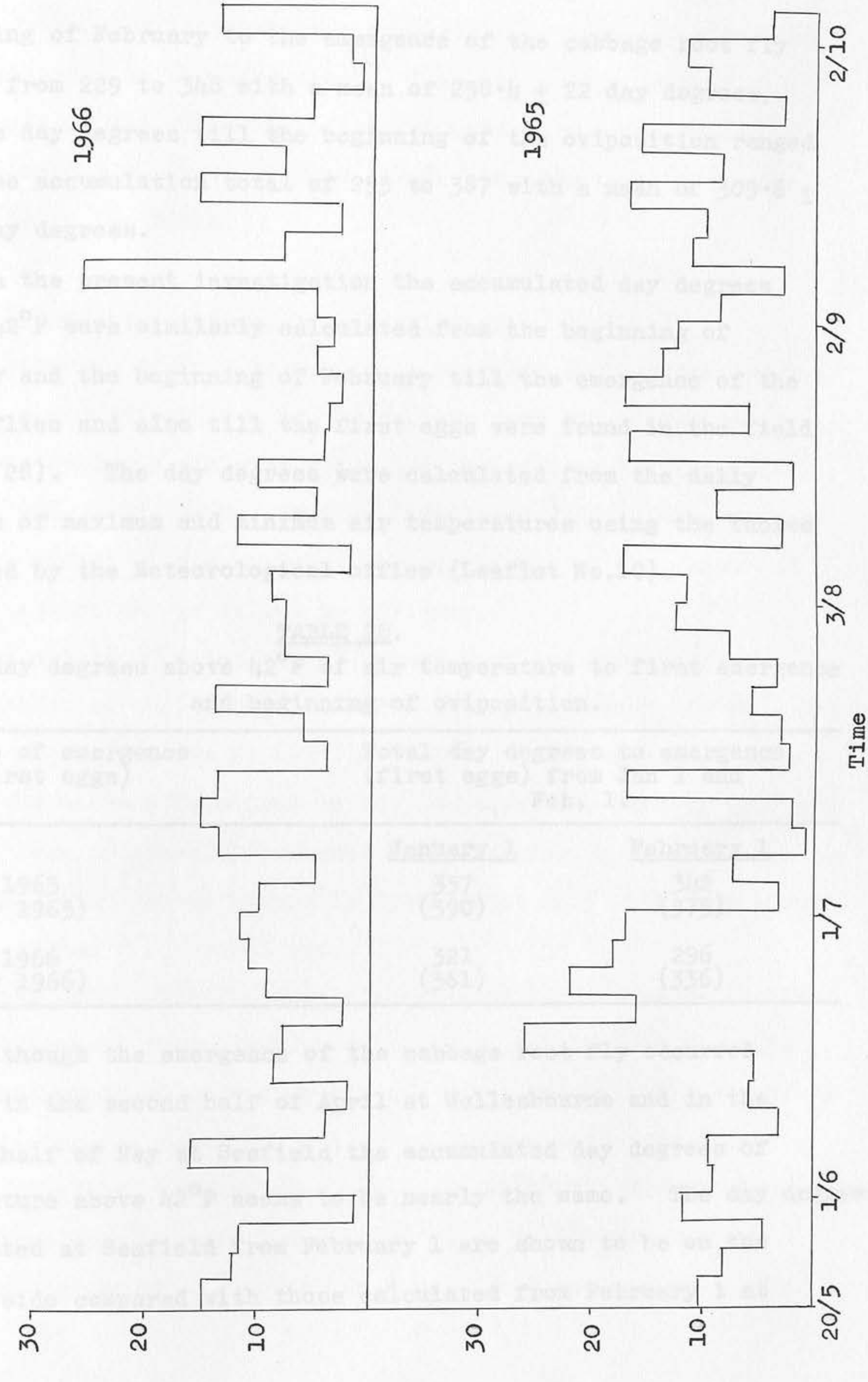


Fig. 35 Wind speed (knots) - Mean per three days

beginning of February to the emergence of the cabbage root fly ranged from 229 to 348 with a mean of 258·4 ± 22 day degrees, and the day degrees till the beginning of the oviposition ranged from the accumulation total of 255 to 387 with a mean of 309·6 ± 27·8 day degrees.

In the present investigation the accumulated day degrees above 42°F were similarly calculated from the beginning of January and the beginning of February till the emergence of the first flies and also till the first eggs were found in the field (Table 28). The day degrees were calculated from the daily records of maximum and minimum air temperatures using the tables provided by the Meteorological office (Leaflet No.10).

TABLE 28.

Total day degrees above 42°F of air temperature to first emergence and beginning of oviposition.

Date of emergence (first eggs)	Total day degrees to emergence (first eggs) from Jan 1 and Feb. 1.	
	January 1	February 1
22 May 1965 (26 May 1965)	357 (390)	342 (375)
17 May 1966 (23 May 1966)	321 (361)	296 (336)

Although the emergence of the cabbage root fly occurred mainly in the second half of April at Wellesbourne and in the second half of May at Seafield the accumulated day degrees of temperature above 42°F seems to be nearly the same. The day degrees calculated at Seafield from February 1 are shown to be on the higher side compared with those calculated from February 1 at

Wellesbourne, and they are more comparable with those calculated from January 1 in the same area. This can be due to the difference of the climatic conditions between the two areas. Soil type is also shown by Read (1958b) to affect the emergence of adults in the field.

Effect of weather conditions on egg-laying:

Weather conditions seem to have a considerable effect on the behaviour and oviposition of the cabbage root fly. Temperature, sunshine, humidity and wind speed are recorded by Brittain (1927), Miles (1951, 1953, 1954), Swailes (1958) and Read (1958b) to have a direct effect on the activity and egg-laying of the flies and the subsequent damage caused to the crops.

Field work by Miles (1954) showed that the threshold of reproduction by the cabbage root fly was approximately 60°F. The rate of egg-laying was highest at 65-70°F. She mentioned that during the seasons from 1948 to 1953 temperatures of over 60°F and long periods of sunshine preceded the discovery of eggs in the field, and they became generally distributed only when warm sunny weather lasted for several days.

These observations completely agree with the results obtained from the present investigation. In 1965 cabbage root fly eggs were first observed on May 26 and the first generation peak period of egg-laying was from June 4 till 16 (Figure 36). Weather records show that temperatures rose over 60°F only during three days in May, the mean maximum temperature being 55·7°F and the sun shone an average of 4·6 hours per day. On June 2, 3 and 4 the temperature rose to 60, 63 and 65 respectively and the sun shone for 4·3, 8·8 and 7·9 hours per day respectively. The egg samples taken on June 4 show the sudden rise in egg numbers in the field. June 9 was the hottest day of the month; temperature rose up to 70^{o}F with 12·9 hours of sunshine, this corresponded with the maximum number of eggs from field samples on June 10. The mean maximum temperature from the beginning till June 15 was 61·4^{o}F with 10 days of temperatures rising over 60^{o}F, and a mean of 4·3 hours sunshine per day.

On June 16 extremely strong wind reaching 30 knots blew from the south west (230 degrees) across the experimental plots (parallel to the hedge) and continued till June 20 with a consistent speed of 24 knots and again with varying speeds from 9 to 24 knots till the end of the month. Egg samples taken from the plots on June 19 show the sudden reduction in the egg numbers present in the field. Temperatures during this period were not notably reduced (varying from 49 to 59 on June 16). The mean maximum temperature from the 16 till the end of the month was 61^{o}F, and on 11 days the temperature exceeded 60^{o}F. The amount of sunshine during this period was increased to 6·8 hours per day. Many fewer eggs were laid by the cabbage root fly second generation. The mean maximum temperature for July and August was 58 and 52; and the sun shone on the average 3·7 and 5·5 hours per day, respectively.

In 1966 cabbage root flies were first observed on May 23 and the first generation peak period of egg laying occurred from May 29 till June 28 (Figure 37). Weather records from the end of April to May 25 show that the mean maximum temperature was 57^{o}F,

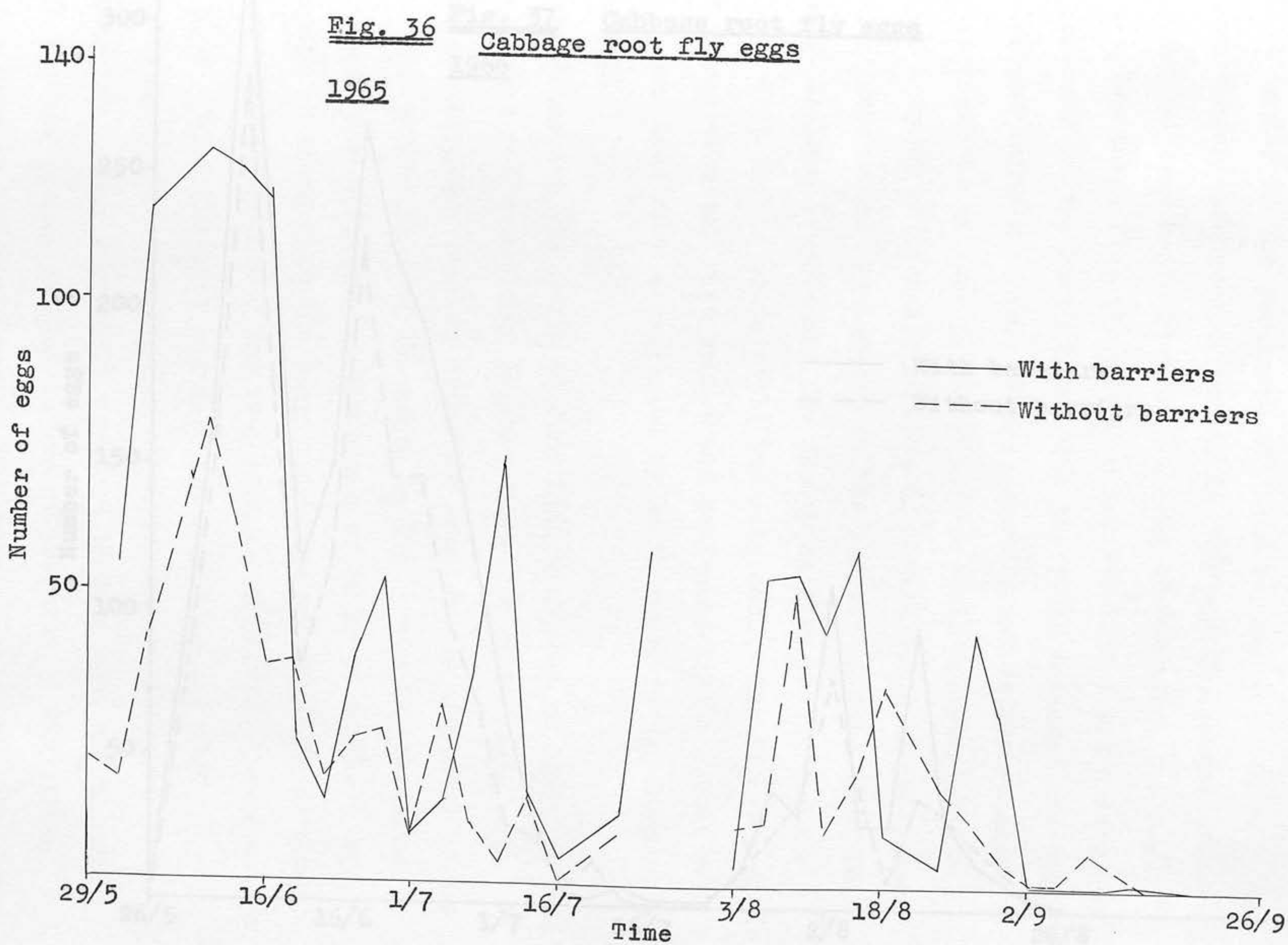


Fig. 36
Cabbage root fly eggs
1965
140
100
50
Number of eggs
With barriers
Without barriers
29/5
16/6
1/7
16/7
3/8
18/8
2/9
26/9
Time

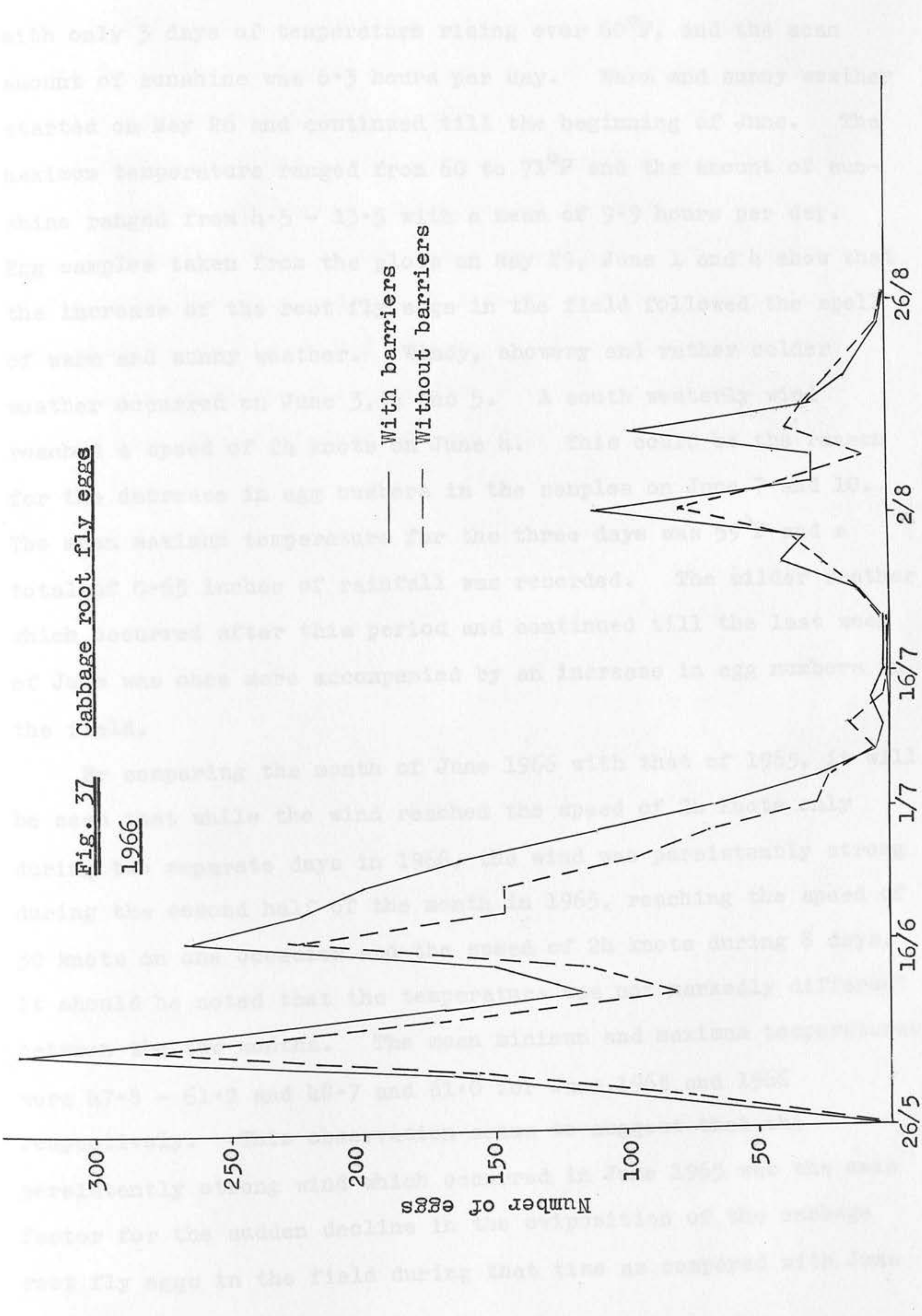


Fig. 37 1966 Cabbage root fly eggs

with only 5 days of temperature rising over 60°F, and the mean amount of sunshine was 6·3 hours per day. Warm and sunny weather started on May 26 and continued till the beginning of June. The maximum temperature ranged from 60 to 71°F and the amount of sunshine ranged from 4·5 - 13·5 with a mean of 9·9 hours per day. Egg samples taken from the plots on May 29, June 1 and 4 show that the increase of the root fly eggs in the field followed the spell of warm and sunny weather. Windy, showery and rather colder weather occurred on June 3, 4 and 5. A south westerly wind reached a speed of 24 knots on June 4. This could be the reason for the decrease in egg numbers in the samples on June 7 and 10. The mean maximum temperature for the three days was 59°F and a total of 0·65 inches of rainfall was recorded. The milder weather which occurred after this period and continued till the last week of June was once more accompanied by an increase in egg numbers in the field.

By comparing the month of June 1966 with that of 1965, it will be seen that while the wind reached the speed of 24 knots only during two separate days in 1966, the wind was persistently strong during the second half of the month in 1965, reaching the speed of 30 knots on one occasion and the speed of 24 knots during 8 days. It should be noted that the temperature was not markedly different between the two months. The mean minimum and maximum temperatures were 47·8 - 61·2 and 48·7 and 61·0 for June 1965 and 1966 respectively. This observation seems to suggest that the persistently strong wind which occurred in June 1965 was the main factor for the sudden decline in the oviposition of the cabbage root fly eggs in the field during that time as compared with June

1966. It is possible that the adult flies could have been driven to shelter and died of starvation or could have been driven away from the plot altogether.

Although mild and warmer weather occurred during July and most of August, the second generation of the root fly was much less intense than that of the first generation. The maximum temperatures for July and August were 63 and 60 respectively. The reduction in the number of eggs in the samples on August 5 and 8 could be due to the excessive rainfall on August 3 and 4 when a total of 2·59 inches of rain fell during the two days.

VI. Field trials and observations on the cabbage root fly in four other sites:

Figures published by the Ministry of Agriculture, Fisheries and Food show that from 1959 to 1964 an average of 3861 acres of Brassicae crops were grown in Scotland for human consumption and that 63% of this acreage was in the South-East, particularly in Mid and East Lothian.

Insecticidal applications and general observations on the cabbage root fly and on the damage caused to the brassicae crops were carried out on four commercial crops during 1966. The Newington, Stony hill and Melville sites are situated in Midlothian and the Seton site is situated in East Lothian. In each site a treatment of 5% diazinon granules at the rate of 0·8 grammes per plant and an untreated control were replicated four times in a randomized block design. The shape and size of the plots in each trial depended on the untreated plants available on each farm. The diazinon granules were applied to the plants using the measure previously mentioned, except at Melville where a spot applicator was used on turnips. Samples containing plants were taken and examined in these experiments as described on page 19.

a) Newington:

Brussels sprouts of the variety "Darkmar 21" were chosen in this farm for the experiment. Each plot contained 100 plants arranged in rows of 10. The experiment was started on May 16 by which date few eggs laid by the first generation flies were already present in the field. 50 plants were examined for eggs by disturbing the soil around the stems with a mounted needle and only 6 were found to have eggs. On June 2 60 per cent. of the plants were found to have a large number of eggs. On July 21 three soil samples per plot each containing one plant were taken. The root fly larvae and pupae were extracted, and the damage caused to each root was recorded. The Carabidae and Staphylinidae found in the samples were also recorded. A 100% control was obtained by the diazinon treatment in that field as no larvae or pupae were found in the samples taken from the treated plots (Table 29). An average of 11·3 larvae and pupae was found per plant in the control plots, causing considerable damage to the roots. The plant weight was significantly (P = 0·05) increased in the treated plots compared with the control.

TABLE 29.

Treatments	Mean / Plot				
	Larvae	Pupae	Root damage	Plant wt. oz.	No. of beetles
Diazinon	0	0	0	1840·8	1·5
Control	18·2	15·8	8·5	857·5	4·8

On September 19 it was observed that a number of plants were missing and some were in a poor state. These plants were counted and the mean number per plot are recorded in Table 30. The total missing plants, poor and very poor were higher in the control plots than in the diazinon treated plots.

TABLE 30

Treatments	Mean number of plants/plot			
	Missing	Poor	Very poor	Total
Diazinon	2·8	6·5	2	11·3
Control	6·5	10·2	5·5	22·2

The crop of sprouts was harvested on two occasions: the first on November 9 by picking the sprouts from the lower parts of the stems, leaving the smaller ones on the top; the second harvest was on February 1 1967 when all the marketable sprouts were gathered. The total crop harvested from each plot in pounds is given in Table 31, where it can be seen that there were more sprouts harvested in the diazinon treated plots compared with the control, but these differences are, however, statistically non-significant.

TABLE 31

Replicate	Control			Diazinon		
	9/11	1/2	Total crop	9/11	1/2	Total crop
1	36	69	105	36	58	94
2	31	49	80	26	67	93
3	17	45	62	31	56	87
4	17	43	60	25	54	79
TOTAL	101	206	307	118	235	353

This farm had been continuously planted with brassicae crops during the last 70 years or more. No insecticides were used during that time and the farmer seems to have been harvesting a reasonable crop every year.

b) Stonyhill:

This is an intensive vegetable growing farm approximately 7 miles from Edinburgh. Aldrin and dieldrin have been used for the control of the cabbage root fly on brassicae crops for many years. Four rows containing about 1000 cauliflower plants of the variety "Feltham Early Supreme" were left untreated while the rest of the field was treated with dieldrin. These plants were mechanically transplanted on May 2.

On May 4 the experiment was carried out and the diazinon treatments were applied, each plot containing 124 plants (31 plants in 4 rows). On the same date one hundred cabbage plants on adjoining ground were examined and no cabbage root fly eggs were found. On June 29 it was noted that a large number of plants were missing throughout the whole field. 13 per cent. of the plants were seen to be absent in the plots. A considerable part of this loss is attributed to non-establishment of plants after transplanting. The total number of poor and damaged plants was 47 in the diazinon treatment compared with 110 in the control.

Plates 14 and 15 show examples of the severely damaged cauliflower plants in the untreated plots. 7 and 13 root fly larvae and pupae were recovered from the plants shown in the two plates respectively. Plate 16 shows the roots of four severely damaged cauliflower plants. The root number 1 had 6 pupae, and number 2 had 17 larvae and pupae. The roots number 3 and 4 belong to the same plants shown in plates 14 and 15 respectively. The cortex of these roots was almost completely eaten away by the pest

Cauliflower plants damaged by the cabbage root fly

Plate 14.

Plate 15.

Plate 16. Cauliflower roots damaged by the cabbage root fly.

and was nearly free from secondary roots; therefore they were totally useless.

On the same date three soil samples per plot each containing a plant were taken at random. An average of 5·2 larvae and pupae per plant were extracted from the samples taken from the control plots compared with 0·5 in the diazinon treated plots (Table 32). The plant weights were considerably reduced in the control plots compared with those in the diazinon treatment. The number of beetles collected from the samples taken from the control plots was considerably greater than those collected from the diazinon treated plots.

TABLE 32.

Treatments	Mean/plot				
	Larvae	Pupae	Root damage	Plant wt. oz.	No. of beetles
Diazinon	1·2	0·2	1·2	892·2	1·2
Control	8·0	7·5	5·5	625·5	6·5

c) Melville:

Brassicae crops have been planted continuously in this farm for a long period of time and insecticides were used frequently for the control of the cabbage root fly. The experiment in this farm was carried out on turnips of the variety "Golden Stone". Diazinon was applied using a spot applicator on May 20, one day after the plants were singled. Each plot measured 10 x 4 yards. Egg laying by the cabbage root fly had already started by that date. It was calculated that 28 per cent of the plants had eggs around the stems.

Three soil and plant samples per plot were taken on July 5 showing that there were more root fly larvae and pupae and more damage to the roots in the untreated plots compared with the diazinon treatment (Table 33). The larvae and pupae found in the treated plots can be due to the fact that the spot applicator does not distribute the insecticide over the whole area around the stem of the plant. Therefore some larvae may escape the treatment. The small Staphylinidae were found to be very abundant in that field, 57 beetles were obtained from one sample. These beetles were significantly reduced in the diazinon treatment. This observation is in agreement with the result obtained from the Seafield experiment.

TABLE 33

Treatments	Mean/plot				
	Larvae	Pupae	Root damage	Plant wt. oz.	No. of beetles
Diazinon	1	2	0·8	1746·2	4
Control	2·5	10	7·5	1143·8	45·2

d) Seton:

This is a large commercial vegetable-growing farm where insecticides have continuously been used. The plots were laid out on May 2 before the egg laying by the cabbage root fly started. Four rows of Brussels sprouts, variety "Long Standard" transplanted on April 13, were chosen for the experiment. Each plot contained 80 plants. Soil and plant samples (three per plot), taken at the beginning of August, by which time the plants were large in size and had powerful root systems that withstood heavy attacks by the root fly before becoming affected. Table 34 shows that although a large number of pupae and empty puparia was found with the roots in the control plots, very little damage was detected at the roots and very little reduction in weight occurred to the roots as they were very rapidly increasing in size.

TABLE 34

Treatments	Mean/plot					
	Larvae	Pupae	Puparium	Root damage	Root wt. oz.	No. of beetles
Daizinon	0·2	2·8	2·2	0·5	386·2	4·5
Control	1·2	18	11·5	1·8	445	6·2

Damage by the cabbage root fly was reported on cauliflowers from East Linton 22 miles S.E. of Edinburgh. On June 17 young plants of the variety "Delta" transplanted three weeks earlier were found to have an average of 19 larvae per plant. Larger cauliflowers in the same field also suffered heavy losses. A large percentage of the plants were wilting (Plate 17) and some were severely damaged (Plate 18). The plant in plate 17 had 13 larvae and 7 pupae while the plant in plate 18 had 21 larvae and 14 pupae.

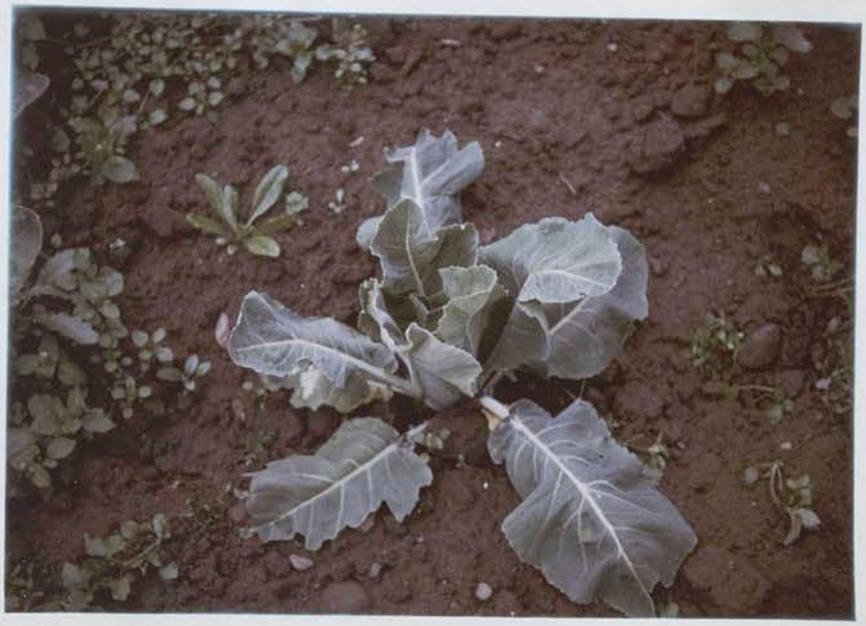


Plate 17. A cauliflower plant wilting due to the infestation by the root fly.

Plate 18. Cauliflower plant severely damaged by the root fly.

DISCUSSION AND CONCLUSIONS

The results of these investigations in south-east Scotland confirm the statements made by workers in the midlands and south of England that the most important biological controlling factor of the cabbage root fly is predation on the eggs by Carabidae and Staphylinidae.

In both years egg laying by the cabbage root fly first generations started in the last week in May and continued till the beginning of July. Far fewer eggs were laid by the second root fly generations, from the third week of July till the end of August. In the two years the Carabid B. guttula occurred in the first part of the season, from May to July. The bulk of T. obtusus occurred from August to October. B. tetracolum, N. brevicollis, Amara spp., L. pilicornis, Pterostichus spp. and C. fossor were common throughout the season. Among the Staphylinidae the smaller species A. gregaria, A. sodalis, A. xanthopus and the larger species O. rugosus occurred in large numbers from May to August, and were most abundant in June when the egg laying by the cabbage root fly first generation was at its peak.

The effect of insecticides on predators of the cabbage root fly:

The use of insecticides in the soil for the control of the cabbage root fly is reported to kill predatory Carabidae and Staphylinidae. Wright et al.(1956) showed that the broadcast of DDT, aldrin and gamma BHC at low rates resulted in increased root fly larvae and pupae in the field and a lower yield of cabbage compared with the control. This was attributed to the mortality of predatory Carabid and Staphylinid in the field. Hughes et al. (1958) reported similar incidents. Coaker (1966) mentioned that residues of aldrin and dieldrin in the soil at concentrations over 0·06 p.p.m., altered Carabid and Staphylinid populations. Wright et al. (1960) pointed out that these losses can be reduced to a minimum by restricting the use of insecticides, wherever possible, to the soil immediately around the plant.

In the present study the insecticides were applied on or under the soil surface around the base of cabbage plants so as to be most concentrated against the eggs and larvae of the pest and least toxic to the predatory beetles.

a) Diazinon:

Both the diazinon treatments consistently reduced the number of beetles in the plots for a period of approximately 11 weeks. The Carabidae trapped in the surface and the sub-surface treatments were significantly reduced (P = 0·01) compared with the control. The Carabidae in the surface treatment were also significantly lower (P = 0·05) than the sub-surface treatment. They were reduced by 59 and 33% in the surface and the sub-surface treatments respectively. This result indicates that the losses of Carabidae were significantly reduced by applying the insecticide granules under the surface of the soil. It was also noted that this treatment lost its toxic effect on the beetles earlier than the surface treatment.

A laboratory trial showed that while most of the Carabidae were killed in the diazinon surface treatment during 24 hours, the beetles in the sub-surface treatment began dying rapidly after three days and they were all dead after one week. It should be noted that the mortality of the beetles in the sub-surface treatment depends on the amount of soil coverage provided for the insecticide.

The Staphylinidae in the surface treatment were significantly reduced ($P = 0{\cdot}05$) compared with both the control and the sub-surface treatment; the difference between the sub-surface treatment and the control being non-significant. The adults were reduced by 47 and 9% in the surface and the sub-surface treatments respectively. These results indicate that the Staphylinidae, while being susceptible to the diazinon applied on the surface, appear to survive the sub-surface treatment very well.

The species which occurred as adults in the field when the diazinon was effective suffered more losses than those which appeared later in the season when the insecticide was less effective. B. guttula, B. tetracolum, Atheta spp., and O. rugosus occurred in large numbers in the first part of the season and suffered substantial losses. As T. obtusus occurred later in the season when the insecticide had more or less lost its effectiveness, this species was not notably affected by the treatments. It was noted that the smaller species of Carabidae were affected more by the diazinon treatments than the larger ones. The smaller species B. guttula, B. lampros, T. obtusus and C. fossor were reduced by 71 and 41% in the surface and the sub-surface treatments respectively compared with the control, while the larger species B. tetracolum, B. bruxellense, Amara spp. and L. pilicornis were reduced by 43 and 23% in the surface and the sub-surface treatments respectively. The largest species N. brevicollis and P. madidus were reduced by

49 and 35% in the two treatments respectively. Similar observations were reported by Mowat (1964) from laboratory trials only in which the smaller Carabidae species, e.g. T. quadristriatus, were affected by lower concentrations of dieldrin in the soil (0·7 p.p.m.) than were the larger species, e.g. F. vulgaris (1·8 p.p.m.) and H. aeneus (1·7 p.p.m.).

b) Chlorfenvinphos:

The Carabidae were shown to be remarkably tolerant towards the chlorfenvinphos insecticide. The application of 10% granules at the rate of 0·5 grammes/plant applied on and under the soil surface reduced the Carabidae in the plots only by 19 and 10% compared with the control respectively. These reductions were non-significant. As it was observed in the laboratory that B. guttula would die when fed on contaminated eggs collected from the surface chlorfenvinphos treatment, the above reduction could be attributed to the mortality of some beetles by feeding on contaminated eggs in the field.

A comparison between the effect of diazinon and chlorfenvinphos on the Carabidae was carried out by laboratory tests. The results of these experiments revealed the wide gap between the two chemicals: while the diazinon surface treatment killed most of the beetles during the first 24 hours, most of the beetles in the chlorfenvinphos treatment lived till the end of the 18 days experiment.

Another experiment showed that while beetles died within one hour as a result of forcing them to come into contact with diazinon granules, few died within one week after coming into contact with the chlorfenvinphos granules.

Mowat (1966) in laboratory tests reported that among the organo-phosphorus the highest LD_{50} found was 2·235 p.p.m. of chlorfenvinphos in soil for Feronia spp. at 4% moisture and the lowest was 0·7 p.p.m. of thionazin for Agonum dorsale at 16% moisture. He also showed that the toxicity of the organophosphorus insecticides increased as the soil moisture increased.

In contrast with the Carabidae, the Staphylinidae were quite susceptible to chlorfenvinphos. Mowat (1966) mentions that A. bilineata and A. bipustulata were at least twice as susceptible to the organophosphorus insecticides as the most susceptible Carabidae species.

The Staphylinid captured in the surface treatment from May 19 till July 16 were significantly lower at 1% level than the control and significantly lower at 5% level in the sub-surface treatment than the control. The catch in the sub-surface treatment was significantly higher ($P = 0{\cdot}05$) than that of the surface treatment. It was calculated that the Staphylinid were reduced by 51 and 25% during this period in the surface and the sub-surface treatments respectively.

This result shows that the Staphylinids, unlike the Carabids, were markedly affected by the chlorfenvinphos treatments. The losses of beetles were also seen to be significantly reduced by applying the insecticide granules under the surface of the soil. The toxic effect of the surface treatment was also found to persist for a longer time compared with the sub-surface treatment.

The Staphylinid captured in the surface treatment from July 16 till the 21 September were significantly lower (P = 0·05) than the sub-surface treatment.

From these results, it may be concluded that the mortality of Carabid and Staphylinid was significantly reduced in the field by the application of the insecticide granules under the soil surface rather than on top of the soil, this was especially marked with the Staphylinid predators.

It was also interesting to discover that the Carabidae were remarkably tolerant to chlorfenvinphos insecticide compared with diazinon.

Since the sub-surface chlorfenvinphos treatment had the least effect on the Carabid and had significantly reduced the Staphylinid mortality compared with the surface treatment, it was considered to be the best treatment for saving the maximum amount of predators in the field.

<u>Predation on the egg stage and the effect of insecticides thereon:</u>

It is clear from the literature on this subject that the Carabidae and Staphylinidae play an important part in controlling the cabbage root fly population in the field by feeding on the egg stage of the pest. Hughes and Salter (1959a) in Wellesbourne showed that 95% of the cabbage root fly individuals died during development. Of these, egg predation contributed about 85·7%. This was later calculated by Coaker and Worrall (1961) to be between 60-70% compared with the total mortality. Hughes (1959b) indicated that an average of 42% of the eggs placed around plants in the field were lost every day. Further work by the same author suggested a linear relationship between the proportion of eggs eaten and the number of predatory beetles captured in the same field. Wright et al. (1960) showed a negative correlation between the number of eggs and the number of beetles obtained from plots with different levels of beetle populations.

In the present investigation Carabidae and Staphylinidae were observed to feed on the cabbage root fly eggs in the laboratory as well as in the field. The barriers used in the field experiments were found to provide a suitable technique for the study of egg predation by beetles. As the barriers allowed the beetles to fall off the area enclosed and prevented beetles from entering it, they kept the area around the stem of cabbage plants almost free from Carabidae. Some of the smaller Staphylinidae, i.e. Atheta spp. were found in the enclosed area especially after rain. As the walls of the barriers were not higher than the general level of the soil surface (Plate 3), they had no deterrent effect on the ovipositing flies. This was confirmed in a laboratory trial.

Predation by beetles was studied by counting eggs from sample plants with and without barriers throughout the egg laying periods of the cabbage root fly. During the1965 first generation of the pest, the mean number of eggs from plants with barriers in the two diazinon treatments and the control was significantly higher ($P = 0 \cdot 01$) than those taken from plants without barriers. Within treatments the difference was only significant in the sub-surface treatment ($P = 0 \cdot 05$). The reduction in egg numbers due to predation in all plots was calculated to be 44% during this period.

During the first generation of 1966 the mean number of eggs from plants with barriers was also significantly higher ($P = 0{\cdot}01$) than those taken from plants without barriers, the differences being highest in the sub-surface treatment ($P = 0{\cdot}01$) followed by the control, then the surface treatment ($P = 0{\cdot}05$). The predation in all plots was calculated to be 31% during this period. These results show that less predation occurred in 1966 than in the same period of 1965. But as the 1966 results are based on double the number of samples and the statistical analysis was of much greater significance, they are therefore more reliable.

In both years egg predation (the difference between the number of eggs sampled from plants with and without barriers) was not significantly affected by the insecticide treatments. But more predation occurred in the sub-surface treatment compared with the surface treatment. This can be due to the mortality of a considerable number of Carabid and Staphylinid in 1965 and mainly the mortality of Staphylinid in 1966. The unexpected lower predation which occurred in the control plots in both years could be the result of the higher population of Staphylinid, compared with the other treatments. These beetles were found to be able to surmount the barriers to some extent. In both years many fewer eggs were laid in the field during the second generation of the cabbage root fly. More eggs and chorions were always obtained from plants with barriers than plants without barriers, but the differences were statistically non-significant.

Predation by Carabidae and Staphylinidae on the egg as well as on the smaller larval stages was found to cause a reduction in the surviving mature larvae and pupae in the field. A reduction of 59% and 50% in the number of mature larvae and pupae occurred in the first and second generation of the cabbage root fly respectively. Although these results were statistically non-significant, they agree with the earlier findings in England of Wright et al. (1956), Hughes et al. (1958, 59) and Coaker (1966). The last author reported that the reduction of predators increased the survival of the cabbage root fly eggs and larvae, thus leading to augmented damage to the crop, which resulted in reduction in yield of up to 70%. The reduction of yield in these observations in S.E. Scotland was considerably less than this figure.

Parasitism by I. rapae and A. bilineata:

The parasites I. rapae and A. bilineata are reported from various parts of the world to parasitise a varying proportion of the cabbage root fly larvae and pupae. In the present study while 64% of the cabbage root fly second generation pupae were parasitised in 1964 by I. rapae (51%) and A. bilineata (13%) in the turnip crop, parasitism by I. rapae was reduced to 19% during the same period of 1965 in the cabbage plots, and no parasitism by A. bilineata was recorded.

In 1966, 13% of the pupae produced by the first generation were parasitised by I. rapae and only 1·1% were parasitised by A. bilineata. During the second generation 17% were parasitised by I. rapae, but none by A. bilineata.

The reduction in parasitism which occurred in 1965 and 1966 compared with 1964, may be due to the use of insecticides in the field. Thionazin, phorate, diazinon and chlordane were used on the turnip crop in 1964, but the samples were taken from untreated plots. Diazinon and chlorfenvinphos were used on cabbage in 1965 and 1966 respectively. Inquiries about the brassicae planted in the field in previous years and the insecticides used, revealed that kale was planted in 1962 and 1963 but no insecticides were used on these crops nor on any other crops in the last 7 years or more.

Similar effects were recorded by many workers. Morris (1960) showed that an application of heptachlor or aldrin eliminiated the parasite A. bilineata and reduced parasitism of T. rapae from 9% to less than 2%. Read (1964) reported that two years after the introduction of insecticides, parasitism in untreated areas of the field dropped from 90% to approximately 10%. Coaker (1966) reported that parasitism by I. rapae, A. bilineata and A. bipustulata decreased by aldrin and dieldrin residues in the soil, the latter two species being more affected.

The control of the cabbage root fly by diazinon and chlorfenvinphos:

Diazinon is known to be a relatively short-lived insecticide. Getzin and Rosefield (1966) mentioned that a rapid loss of its toxicity occurred during the first 8 weeks, and this was followed by a much slower decline. In the present study both the diazinon treatments gave a 100% control of the cabbage root fly first generation. This was for over a period of about 11 weeks, after which the insecticide provided very little or no protection against the pest. It was observed that the sub-surface treatment gave protection against the pest for a slightly longer period of time compared with the surface treatment. This is likely because the granules were less affected by weather conditions. As the attack by the cabbage root fly was not heavy in 1965, no apparent differences were noted on the crop between the treatments and the control.

The chlorfenvinphos on the other hand is shown by Trought and Heath (1965) to be a persistent insecticide. Wright (1965) reported that the insecticide gave a high level of root fly control for a period of two successive years. In the present investigation, the chlorfenvinphos was extremely active against the pest, giving a 100% control throughout the whole season in both the surface and the sub-surface treatments. More yield and more marketable cabbage heads were harvested in the treated plots than in the control, but the differences were, however, statistically non-significant. Chlorfenvinphos had a greater ovicidal effect on the pest compared with diazinon; and both the insecticides had a much higher ovicidal effect when applied on the surface than under the soil surface.

Effect of weather:

The cabbage root fly adult emerged in the field on May 22 and May 17 in 1965 and 1966 respectively. An accumulation of 342 and 296 day degrees temperature above $42^{o}F$ respectively was calculated from February 1 till the emergence of the adults in the field. These figures are comparable to those calculated by Coaker and Wright (1963) from January 1 till the emergence of the adults in the second half of April at Wellesbourne. The same relationship was found between the accumulated day degrees temperature above 42°F and the beginning of oviposition in the field. More research is needed in order to develop this method so that accurate anticipation of the date of adult emergence and the beginning of oviposition in the field can be made.

The results also agree with Miles (1954) that temperatures of over 60°F and long periods of sunshine preceded oviposition in the field.

Weather conditions were found to have a marked effect on the rate of oviposition. While warm and mild weather was accompanied by an increase in egg numbers, cold, windy and rainy weather resulted in a lower rate of egg-laying. Persistently strong wind reaching 30 knots caused a sudden reduction in egg-laying in the field.

With knowledge of the time oviposition is likely to begin in the field and the effect of different weather conditions, the time and strength of attacks by the pest can be anticipated and more accurate control measures can be adopted.

SUMMARY

Two generations of the cabbage root fly occurred annually, the main periods of egg laying being from the last week of May till the beginning of July, and from the third week of July till the end of August. The population of the first generation was higher and so more damaging to the crops.

Predation on the egg stage by Carabid and Staphylinid beetles was confirmed to be the most important biological controlling factor of the pest. Bembidion spp., T. obtusus, Atheta spp. and O. rugosus were the principal predators.

In both years predation by beetles reduced significantly ($P = 0{\cdot}01$) the cabbage root fly egg population in the field. The reduction in the egg numbers of the root fly first generation due to predation was calculated to be 44 and 31 per cent in 1965 and 1966 respectively.

Diazinon and chlorfenvinphos granules were applied around the base of cabbage plants on and under the soil surface. Both the diazinon treatments reduced significantly ($P = 0{\cdot}01$) the number of Carabid predators in the field compared with the control. These losses were significantly reduced ($P = 0{\cdot}05$) in the sub-surface treatment compared with the surface treatment.

The Staphylinids in the surface treatment were significantly reduced ($P = 0{\cdot}05$) compared with both the control and the sub-surface treatments, the difference between the sub-surface and the control was non-significant.

The Carabids were found to be remarkably tolerant to the chlorfenvinphos insecticide. The number of Carabids captured in

the treated plots did not differ from that of the control. On the other hand the Staphylinids in the surface treatment were significantly reduced at 1% level, and in the sub-surface treatment at 5% level compared with the controls. The difference between the surface and the sub-surface treatments was also significant at 5% level.

Despite the reduction in beetle population by the insecticide applications, in both years the predation on the egg stage of the cabbage root fly was not significantly affected by the treatments.

51 per cent. parasitism by I. rapae and 13 per cent. by A. bilineata were recorded in 1964. This was reduced to 19 per cent. all by I. rapae in the same period in 1965 and 17 per cent. in 1966. This reduction could be due to the use of insecticides in the field.

Diazinon gave a 100 per cent. control of the cabbage root fly over a period of about 11 weeks, and gave very little protection thereafter. The chlorfenvinphos was extremely active against the pest giving a 100 per cent. control throughout the season.

Weather conditions were noticed to have a marked effect on the rate of oviposition by the cabbage root fly. Persistently strong wind caused a large reduction in egg-laying in the field.

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APPENDIX I

Number of beetles captured over 3 day periods, in 3 pitfall traps per plot in the two diazinon treatments and the control (1965)

TABLE 1. Family Carabidae

	Con.			S.			S.S.		
	C	D	G	A	F	I	B	E	H
21/5/65	11	15	17	5	3	3	6	9	5
24/5	11	5	22	1	4	3	3	4	6
27/5	7	10	12	4	5	7	5	11	8
30/5	5	7	10	2	2	2	3	7	7
2/6	6	19	11	2	3	7	3	5	8
5/6	5	5	6	1	1	2	3	4	4
8/6	2	6	6	1	3	4	2	4	4
14/6	8	15	21	2	6	3	4	4	4
17/6	6	13	15	3	7	4	7	7	8
20/6	9	9	10	5	2	4	6	4	6
23/6	11	11	10	5	5	7	9	4	9
26/6	10	7	13	4	7	4	6	10	6
2/7	11	18	18	5	11	8	5	11	15
5/7	13	14	19	3	4	4	9	12	15
8/7	9	9	9	2	6	5	16	15	18
11/7	9	17	14	0	4	4	4	11	7
18/7	7	9	11	6	10	9	9	10	5
21/7	7	7	7	3	4	3	6	3	2
TOTAL	147	196	231	54	87	83	106	135	137
6/8	11	15	20	13	17	11	15	23	11
9/8	24	17	25	17	21	15	18	20	14
12/8	35	24	18	27	32	19	21	19	26
15/8	24	30	13	13	23	15	24	22	22
18/8	27	34	24	34	31	22	21	24	24
21/8	20	9	13	17	13	19	16	27	13
24/8	33	21	21	22	24	27	27	33	21
27/8	28	25	27	27	29	35	37	27	27
30/8	39	28	14	18	21	34	20	28	16
2/9	17	27	12	31	31	21	24	18	15
17/9	32	23	28	25	26	30	34	28	28
8/10	24	24	16	24	24	17	30	12	15
11/10	24	15	27	19	17	19	35	22	17
14/10	25	19	16	20	20	16	33	19	18
17/10	46	24	24	26	23	44	28	27	47
20/10	21	20	21	14	15	29	28	21	37
23/10	8	7	10	13	12	9	18	8	10
TOTAL	438	362	329	360	379	382	429	378	361

TABLE 2. B. guttula and B.lampros.

	Con.			S.			S.S.		
	C	D	G	A	F	I	B	E	H
21/5/65	5	7	8		2		3	2	1
24/5	3	2	11		2		1	1	1
27/5	4	4	10	1	2	4	1	4	5
30/5	2	4	7			1		3	3
2/6	2	10	8	1	1	1	1	2	3
5/6	2	3	1	1	1		3	4	1
8/6	2	0	2		2	1	2	2	2
14/6	2	9	8		3	1	2		1
17/6	3	7	7	2	5	1	2	3	4
20/6	1	4	4	1	1		1		
23/6		3	5	1	1		3		4
26/6	3	1	4	3		1	2	2	1
2/7	2	10	12	3	4		4	4	1
5/7		5	3		3		4	2	2
8/7	1	1	2	1		1	1	5	2
11/7	1	4	2		3	1	2		1
18/7		2							1
21/7									
TOTAL	33	76	94	14	30	12	32	34	33
6/8		3							
9/8					1				
12/8					1				
15/8									
18/8									1
21/8								1	
24/8			1						
27/8				1					
30/8					1				
2/9		1							
17/9									
8/10							1		
11/10						1			
14/10									
17/10						1	1		
20/10									
23/10									
TOTAL	0	4	1	1	3	2	2	1	1

TABLE 3. T. obtusus.

	Con.			S.			S.S.		
	C	D	G	A	F	I	B	E	H
21/5/65	2							1	
24/5			1						1
27/5		1			1				
30/5									
2/6			1						1
5/6									
8/6									
14/6		1		1					
17/6						1		1	1
20/6	1							1	
23/6	3	1			1		1	1	
26/6	1	2	2		2	1	1	2	1
2/7		1				1	1		2
5/7	3		3		3			6	3
8/7			2		1		2	6	4
11/7	3	2	5			2	1	4	1
18/7	2		4	2	3	1	6	6	2
21/7	1	4	2	1	2		2	2	
TOTAL	16	12	20	4	13	6	14	30	16
6/8	10	11	18	9	14	9	10	20	10
9/8	18	5	22	14	17	13	15	16	11
12/8	26	3	11	18	26	8	16	17	19
15/8	22	17	8	9	20	15	18	19	14
18/8	27	19	22	30	25	10	17	22	22
21/8	19	9	11	15	8	17	8	24	11
24/8	27	20	18	13	21	24	22	13	20
27/8	14	20	23	23	7	28	31	15	17
30/8	19	18	12	15	16	20	12	25	13
2/9	13	25	12	24	3	20	24	10	14
17/9	25	21	23	22	22	23	18	22	20
8/10	15	20	14	12	12	11	22	10	11
11/10	19	11	23	13	17	16	30	17	16
14/10	23	16	14	17	17	13	27	14	16
17/10	29	23	22	15	15	34	22	23	33
20/10	18	18	20	11	14	26	25	18	31
23/10	3	7	7	11	11	6	16	9	9
TOTAL	327	263	280	271	265	293	333	294	287

TABLE 4. B. tetracolum and B. bruxellense

	Con.			S.			S.S.		
	C	D	G	A	F	I	B	E	H
21/5/65	4	6	6	4	2	1	3	4	1
24/5		3	6		2	2		2	4
27/5	3		1	3	2	3	3	5	3
30/5	2	3	2	1	2	1	3	4	3
2/6	4	2	1		1	5	1	2	3
5/6			3			1			
8/6									1
14/6	1	2	5	1	2			1	
17/6	2	2	4		1	2	1	1	1
20/6	1	1	1	3		2			
23/6	4	1	2	2	1	2	1	1	2
26/6	2	2	3	1		2		1	
2/7	8	3	4	2	7	3		6	11
5/7	8	4	6	3	1	2	2	3	4
8/7	5	2	2		2	2	3	4	5
11/7		4	1				2	3	3
18/7	2	2	4		6	1		1	
21/7					1				
TOTAL	46	37	51	20	30	29	19	38	41
6/8	1		1		2	1		1	
9/8	1	3	1	2	1		3	3	2
12/8	5	3			2	1	5	3	3
15/8	1	1			3				1
18/8		1	1		1				1
21/8			1						
24/8	1		1	1		1	3	5	1
27/8	1	1					5		
30/8							3		
2/9								2	
17/9				1			1		1
8/10	2	2	1		5	1	4	1	
11/10	3	2	3				2	2	
14/10	1	1	1	2	1	1	5	2	
17/10	11	1	1	2	5	3	1	2	5
20/10	3	1		2	1	2	3	3	1
23/10	3		2			2	1	1	1
TOTAL	33	16	13	10	21	12	36	25	16

TABLE 5. N. brevicollis

	Con.			S.			S.S.		
	C	D	G	A	F	I	B	E	H
21/5/65									
24/5							1		
27/5									
30/5									
2/6		1	1	1	1		1	1	1
5/6	3	1	8						
8/6		2	3		1	1			
14/6	1		3						
17/6		2		1					
20/6	2	1	2			2	1	3	2
23/6	2	1	3		1	3	2	2	3
26/6	1	2	3		2		2	4	1
2/7		1							
5/7			1		1	1		1	
8/7		1							
11/7			2						
18/7		1	1			3	1		1
21/7				1			1	1	
TOTAL	9	13	27	3	6	10	9	12	8
6/8		1				1			
9/8	2								1
12/8			2						1
15/8		1	1				1		
18/8		1	1	2	2	1			
21/8	1					2	3		
24/8	4	1		1	2			2	1
27/8	6	4	3	2	3	2		4	1
30/8	7	2		4	4	3	3	2	
2/9	3	1		1	1			3	2
17/9	7	2	4	2	4	7	3	6	5
8/10	7	2	1	12	5	5			2
11/10	1	1		5		1	2	2	
14/10	1	2				2	1	1	1
17/10	4		1	7	1	6	3	2	7
20/10				1		1			2
23/10			1	1			1		
TOTAL	43	18	14	38	22	31	17	22	23

TABLE 6. Amara spp.

	Con.			S.			S.S.		
	C	D	G	A	F	I	B	E	H
21/5/65								1	
24/5			1						
27/5									
30/5				1					1
2/6									
5/6									1
8/6				1					
14/6									
17/6							1		
20/6			1	1					
23/6				1			1		
26/6				1	2				
2/7						1			
5/7							1		
8/7					1		1		1
11/7	2					1			1
18/7	1			1	1	3	1		
21/7	1	2							
TOTAL	4	2	2	6	4	5	5	1	4
6/8			1		1				1
9/8	1	4	2	1	2	2		1	
12/8	2	3	3		3	2			1
15/8	1								1
18/8				1		1	1	1	
21/8				2	1			1	
24/8									
27/8	2				1	4	1	2	1
30/8	1	2				1	1		
2/9			1			1			
17/9									
8/10									
11/10							1		
14/10								1	
17/10									
20/10									
23/10									
TOTAL	7	9	7	4	8	11	4	6	4

TABLE 7. L. pilicornis

	Con.			S.			S.S.		
	C	D	G	A	F	I	B	E	H
21/5/65			1						
24/5			3	1				1	
27/5		4						1	
30/5									
2/6									
5/6		1							1
8/6						1		2	
14/6			2		1	1		1	3
17/6		1	2				1		
20/6	1		1		1		2		1
23/6		1		1	1		1		
26/6			1				1	1	2
2/7		2	1						
5/7	1	2	1				2		1
8/7					1		1		2
11/7	2	3	1					1	
18/7	1	2		1		1	1	3	1
21/7	5		2			2	2		1
TOTAL	10	16	15	3	4	5	11	10	12
6/8									
9/8									
12/8									
15/8									
18/8							1		
21/8									
24/8	1					1		1	
27/8				1					1
30/8	1						1		
2/9	1								
17/9							1		2
8/10					1			1	
11/10	1	1		1					
14/10					1			1	
17/10	1				1				
20/10		1							1
23/10				1		1			1
TOTAL	5	2	0	3	3	2	3	3	5

TABLE 8. Pterostichus spp.

	Con.			S.			S.S.		
	C	D	G	A	F	I	B	E	H
21/5/65									
24/5									
27/5							1		
30/5									
2/6		1							
5/6									
8/6		1							
14/6	1	1		1					
17/6								1	
20/6		1					1		
23/6		1				1			
26/6									
2/7									
5/7									1
8/7		1		1	1	2	2		
11/7		1		1			1		
18/7	1			1		1			
21/7		1		1		1			2
TOTAL	2	8	0	5	1	5	5	1	3
6/8				1			3		
9/8									
12/8		2		3				2	
15/8		2	1	1			2	1	2
18/8			1		2	3	1		
21/8			1		1		1		1
24/8	1		2	2			1	2	3
27/8			1			1			1
30/8	1	2		3		1			1
2/9			2	1	1			2	
17/9									
8/10									2
11/10									
14/10									
17/10									
20/10									
23/10									
TOTAL	2	6	8	11	4	5	8	7	10

TABLE 9. C. fossor

	Con.			S.			S.S.		
	C	D	G	A	F	I	B	E	H
21/5/65		1							
24/5									
27/5			1					1	
30/5	1		1						
2/6									
5/6						1			1
8/6		3	1						
14/6	1	2	2					2	
17/6			2				1		
20/6	2								3
23/6	1								
26/6									
2/7		1	1			1			
5/7	1		1			1			
8/7		1	1						
11/7	1	2	1					2	1
18/7	1	1	1						
21/7			2						
TOTAL	8	11	14	0	0	3	1	5	5
6/8									
9/8	2								
12/8	1		1						
15/8							1		
18/8									
21/8									
24/8									
27/8									
30/8			1						
2/9									
17/9									
8/10									
11/10									
14/10									1
17/10									
20/10									
23/10									
TOTAL	3	0	2	0	0	0	1	0	1

TABLE 10. Notiophilus spp.

	Con.			S.			S.S.		
	C	D	G	A	F	I	B	E	H
21/5/65									
24/5						1			
27/5									
30/5									
2/6									
5/6									
8/6									
14/6									
17/6					1				
20/6									
23/6									
26/6									
2/7									
5/7		1							
8/7									
11/7			1						
18/7									
21/7			1						
TOTAL	0	1	2	0	1	1	0	0	0
6/8									
9/8									
12/8								1	
15/8									
18/8									
21/8									
24/8					1				
27/8	1								
30/8								1	
2/9									
17/9									
8/10					1				
11/10			1			1			1
14/10			1		1				
17/10				2					1
20/10			1						
23/10									
TOTAL	1	0	3	2	3	1	0	2	2

TABLE 11. Family Staphylinidae

	Con.			S.			S.S.		
	C	D	G	A	F	I	B	E	H
21/5/65	18	16	21	2	8	3	6	11	17
24/5	16	23	39	3	10	5	13	19	27
27/5	10	10	14	5	6	5	4	5	13
30/5	10	10	29	1	2	5	7	11	17
2/6	22	28	35	10	17	12	20	29	29
5/6	25	15	34	15	18	11	18	26	19
8/6	18	16	17	5	6	3	18	22	22
14/6	17	16	9	15	13	19	17	29	23
17/6	12	13	15	10	12	7	18	16	8
20/6	6	6	6	2	7	2	12	4	6
23/6	8	4	18	8	1	3	8	9	11
26/6	9	12	14	7	12	7	8	9	10
2/7	29	50	42	17	38	17	26	16	38
5/7	6	25	26	8	14	15	19	17	21
8/7	16	6	21	6	6	14	14	13	23
11/7	10	8	6	9	8	9	6	14	11
18/7	9	21	19	5	13	6	6	14	35
21/7	6	15	19	9	14	6	7	8	12
TOTAL	247	294	384	137	205	149	227	272	342
6/8	9	9	17	12	13	8	18	15	11
9/8	7	12	8	4	26	8	5	8	11
12/8	10	10	7	3	12	18	11	8	11
15/8	10	1	3	4	4	6	3	0	2
18/8	7	2	9	0	6	2	6	4	1
21/8	5	8	12	6	4	10	3	8	2
24/8	6	8	12	2	14	16	8	9	21
27/8	3	6	4	2	14	13	1	1	0
30/8	12	7	4	9	5	10	4	9	10
2/9	8	7	7	4	2	3	5	0	0
17/9	5	7	2	6	2	5	10	1	8
8/10	1	3	4	5	1	0	0	3	0
11/10	11	8	6	4	8	18	17	8	12
14/10	5	7	1	5	3	15	5	11	13
17/10	17	10	13	9	7	15	16	8	14
20/10	18	7	11	4	13	6	13	13	21
23/10	11	6	8	3	2	8	8	9	7
TOTAL	145	118	128	82	106	151	133	115	144

TABLE 12. Atheta spp.

	Con.			S.			S.S.		
	C	D	G	A	F	I	B	E	H
21/5/65	18	12	18	1	3		5	4	9
24/5	11	15	27	2	4	5	9	13	24
27/5	7	9	14	4	4	5	2	5	11
30/5	8	6	16	1		3	6	7	11
2/6	15	14	20	4	9	8	11	20	17
5/6	14	8	13	6	8	7	10	19	8
8/6	15	9	12	5	5	3	17	21	20
14/6	16	14	6	9	12	9	14	25	20
17/6	12	11	14	9	12	7	14	10	8
20/6	6	4	6	1	7	2	7	3	5
23/6	8	6	16	8	1	4	8	8	10
26/6	9	11	13	6	12	7	8	8	9
2/7	15	28	23	7	30	13	16	10	24
5/7		13	16	7	8	10	12	10	4
8/7	11	7	14	2	4	3	2	8	15
11/7	7	7	4	7	7	7	6	12	10
18/7	8	16	16	4	7	3	2	10	22
21/7	3	11	12	6	10	2	5	4	6
TOTAL	183	201	260	89	143	98	154	197	233
6/8	7	9	15	9	10	8	8	13	11
9/8	7	5	7	4	5	5	5	7	11
12/8	10	7	5	2	11	11	10	8	9
15/8	10		2	3	4	5	2		1
18/8	6	1	6		4	1	4	4	
21/8	5	7	7	3	2	7	1	6	2
24/8	5	6	8	1	12	16	8	13	12
27/8	1	5	6	2		3	1	1	
30/8	5	4	2	6	4	8	2	7	7
2/9	7	5	5	3	4	1	4		
17/9	5	7	2	5	2	4	7	1	8
8/10	1							1	
11/10		1	1	1		2		1	3
14/10		4		2	2	8		2	6
17/10	3	3	5	1		1	2	1	1
20/10		2	1	2	4		6	5	2
23/10	3	2	1				1	2	
TOTAL	75	68	73	44	64	80	61	72	73

TABLE 13. O. rugosus.

	Con.			S.			S.S.		
	C	D	G	A	F	I	B	E	H
21/5/65		4	3		4	3	1	6	7
24/5	5	6	11	1	6		4	6	3
27/5	3	1		1	2		2		1
30/5	2	1	5		2	1	1	2	4
2/6	7	3	5	6	5	3	8	5	10
5/6	11	6	9	9	10	4	7	4	9
8/6	3	4	3				1	1	1
14/6	1	1	3	1	1	3	2	4	3
17/6		2	1	1			4	2	
20/6							1	1	1
23/6			2					1	1
26/6		1	1	1				1	1
2/7	14	21	19	10	8	4	7	5	13
5/7	4	12	4	1	6	4	5	5	7
8/7	3	2	5		1	5	2	3	5
11/7	3	1	2	1		1		2	1
18/7	2	4	2		1		2	3	11
21/7	3	3	3		2		2	4	
TOTAL	61	72	78	32	48	28	49	55	78
6/8	2		1	1	2			2	
9/8		2	1		1	2		1	
12/8			2		1	1		2	1
15/8		1				1			
18/8			3						1
21/8			2	3	1	1	1	2	
24/8	1	2	1		2			3	4
27/8	1	1							
30/8	3	1	1		1		1	2	
2/9	1	1							
17/9				1		1			
8/10		2	1						
11/10		1	1						1
14/10		1		1					
17/10	1	1							1
20/10	2					1		1	
23/10									
TOTAL	11	13	13	6	8	7	2	13	8

TABLE 14. L. longelytrata

	Con.			S.			S.S.		
	C	D	G	A	F	I	B	E	H
21/5/65									
24/5		2							
27/5									1
30/5		3	8			1		2	2
2/6		4	10		3	1	1	4	2
5/6		1	1					3	2
8/6			2		1				1
14/6						1			
17/6									
20/6				1					
23/6			2					1	1
26/6		1	1		1			1	1
2/7									
5/7									
8/7									
11/7									
18/7									
21/7									
TOTAL	0	11	24	1	5	3	1	11	10
6/8									
9/8									
12/8									
15/8									
18/8									
21/8									
24/8									
27/8									
30/8									
2/9									
17/9									
8/10		1	3	3			3		
11/10	11	6	3	3	7	16	16	6	8
14/10	4	2	0	2	1	6	4	7	6
17/10	12	6	8	8	6	14	14	7	12
10/10	16	5	8	2	8	4	7	7	17
23/10	8	4	7	2	2	8	7	7	7
TOTAL	51	24	29	20	24	48	51	34	50

TABLE 15. Philonthus spp.

	Con.			S.			S.S.		
	C	D	G	A	F	I	B	E	H
21/5/65									
24/5									
27/5									
30/5									
2/6									
5/6							1		
8/6									
14/6		1					1		
17/6									
20/6									
23/6									
26/6									
2/7									
5/7		1						1	
8/7	1					2			
11/7									
18/7			1		1	1		1	
21/7			1		1	2			
TOTAL	1	2	2	0	2	5	2	2	0
6/8			1	1					
9/8		1							
12/8									1
15/8									
18/8	1								
21/8						1			
24/8									
27/8									
30/8						1			
2/9									
17/9									
8/10				1	1				
11/10			1		1			1	
14/10	1					1	1	2	
17/10	1				1				
20/10			1				1		2
23/10			1						
TOTAL	3	1	4	2	3	3	2	3	3

TABLE 16. H. riparius (Elateridae)

	Con.			S.			S.S.		
	C	D	G	A	F	I	B	E	H
21/5/65									
24/5	1						1		
27/5		1							
30/5									1
2/6									
5/6									1
8/6									
14/6							1		
17/6									
20/6									
23/6									
26/6	2				1				1
2/7									
5/7									
8/7							1		
11/7									
18/7									
21/7							1		
TOTAL	3	1	0	0	1	0	4	0	3
6/8									
9/8									
12/8	1								
15/8									
18/8									
21/8									
24/8							2		
27/8									
30/8									
2/9									
17/9									
8/10									
11/10									
14/10									
17/10									
20/10									
23/10									
TOTAL	1	0	0	0	0	0	2	0	0

APPENDIX II

Number of beetles captured over 3 day periods, in 3 pitfall traps per plot in the two chlorfenvinphos treatments and the control (1966)

TABLE 17. Family Carabidae.

	Con.			S.			S.S.		
	C	E	H	A	D	I	B	F	G
22/5/66	12	7	10	9	4	2	7	10	8
25/5	5	7	10	6	3	1	6	5	4
28/5	7	10	9	5	9	7	8	12	10
31/5	9	8	10	12	6	10	8	4	10
3/6	11	7	9	7	7	20	10	9	8
6/6	15	17	19	18	13	14	19	19	15
9/6	14	9	2	8	4	8	14	5	8
12/6	18	11	7	12	5	10	11	7	6
15/6	13	9	9	14	4	16	11	8	6
18/6	14	13	9	11	7	11	14	5	9
22/6	12	5	5	9	9	8	6	8	4
25/6	8	8	8	8	6	4	9	13	8
28/6	8	8	12	8	3	3	4	4	6
1/7	2	4	8	3	6	9	7	2	10
4/7	4	6	4	2	5	3	5	7	4
7/7	4	6	6	1	3	4	7	4	3
10/7	9	8	4	1	3	8	6	9	9
16/7	8	9	8	5	3	6	9	5	1
TOTAL	173	152	149	139	100	144	161	136	129
19/7	8	2	4	5	6	6	9	6	2
24/7	7	7	6	6	4	6	8	6	2
27/7	7	10	10	7	7	5	10	12	4
30/7	8	10	12	13	12	3	14	11	7
2/8	21	10	10	11	11	13	12	9	10
5/8	19	13	16	10	9	7	9	7	2
9/8	10	12	10	16	14	15	27	17	9
12/8	17	15	23	12	16	1	18	14	19
18/8	16	11	41	7	39	44	16	10	40
21/8	22	10	36	16	34	34	20	13	34
24/8	19	10	26	19	25	34	19	11	21
27/8	19	19	18	17	26	37	20	13	29
30/8	44	23	21	27	5	38	14	24	35
15/9	12	35	24	18	15	18	12	18	29
18/9	29	27	30	26	23	16	9	21	40
21/9	24	17	13	30	29	5	9	23	28
TOTAL	282	231	300	240	275	282	226	215	311

TABLE 18. B. guttula and B. lampros.

	Con.			S.			S.S.		
	C	E	H	A	D	I	B	F	G
22/5/66	2	4	2	2		2	2	8	7
25/5		1	2	2		1	1	2	2
28/5	3	2	3	2	1	3	2	2	2
31/5	5	4	5	6	2	8	2	2	6
3/6	7	5	5		3	12	3	5	5
6/6	4	17	9	10	2	6	7	14	7
9/6	4	4		3	2	2	4	2	4
12/6	3	4	1	1	2	1	4	1	4
15/6		2	1	1	1	1	2		2
18/6		2	1	1	2	1			
22/6	1					1			
25/6	1			1	2	1	2	2	3
28/6			1		1	1		1	
1/7		1	1			2	3		3
4/7		4	1	1			3	2	2
7/7		1			1	1	1	1	
10/7								1	
16/7		2		1					
TOTAL	30	53	32	31	19	43	36	43	47
19/7						1	1		
24/7								1	
27/7									
30/7		1		1					
2/8									
5/8									
9/8									
12/8			1						
18/8									
21/8									
24/8									
27/8						1			
30/8				1					
15/9									
18/9									
21/9	1								
TOTAL	1	1	1	2	0	2	1	1	0

TABLE 19. *T. obtusus*.

	Con.			S.			S.S.		
	C	E	H	A	D	I	B	F	G
22/5/66								1	1
25/5		2	3	1	1				
28/5			1				1		1
31/5		1	1						
3/6									
6/6									
9/6									3
12/6		1				2			
15/6						2			
18/6									
22/6					1	1	1	1	
25/6		2			1			1	2
28/6			1	2	1			1	3
1/7			2			1	1		4
4/7	3		2		2	2	1		1
7/7		2	2				1	1	1
10/7		2	2	1		1	3		5
16/7	2					1	3	1	
TOTAL	5	10	14	4	6	10	11	6	21
19/7	3	1	2	3	3	3	4	2	1
24/7	3	3	1	1	2	2	3	3	1
27/7	4	4	3	4	4		6	6	3
30/7	4	5	5	5	2	1	7	4	2
2/8	14	5	3	7	7	8	9	5	4
5/8	15	10	4	9	7	4	5	3	1
9/8	6	7	6	10	5	8	15	13	6
12/8	11	8	17	7	10		12	5	13
18/8	9	7	35	5	22	32	10	5	29
21/8	17	7	31	10	27	27	15	9	31
24/8	13	9	19	10	22	30	15	5	18
27/8	16	12	13	13	21	32	18	10	24
30/8	41	14	15	20	4	24	10	22	32
15/9	3	24	18	11	13	7	3	10	10
18/9	9	15	13	21	5	11	4	15	30
21/9	8	10	9	23	18	1	4	15	23
TOTAL	176	141	192	159	172	190	140	132	228

TABLE 20. B. tetracolum and B. bruxellense

	Con.			S.			S.S.		
	C	E	H	A	D	I	B	F	G
22/5/66	4	1	1	6	3		3		
25/5	3	1	5	2	1		3	2	1
28/5	1	5	5	3	8	4	4	7	7
31/5	1	2	3	6	4	1	4	1	3
3/6	1	1	1	3	3	6	4	4	3
6/6	8		7	6	9	4	10	3	5
9/6	5	4			1		2	1	
12/6	4	2			1			1	
15/6	1			1		1		1	1
18/6			1			2			
22/6			1						
25/6			1						1
28/6								1	
1/7									
4/7								1	
7/7									
10/7									
16/7								1	
TOTAL	28	16	25	27	30	18	30	23	21
19/7								1	1
24/7		1		2					
27/7		1						1	
30/7							2		1
2/8	1		1				1		1
5/8		1		1			4		
9/8	1			1	3		6		1
12/8		3	3	3	2		2		3
18/8		1	4		1	1			4
21/8	2		3	3	1	1	1		1
24/8	2		5	1	1	1	1		1
27/8			1	1	2			1	2
30/8			1	2					2
15/9		2	3						
18/9		3	1		2				
21/9									
TOTAL	6	12	22	14	12	3	17	3	17

TABLE 21. N. brevicollis

	Con.			S.			S.S.		
	C	E	H	A	D	I	B	F	G
22/5/66									
25/5									
28/5	1						1		
31/5									
3/6			2	1					
6/6	1		1	1	2			1	3
9/6	4	1		3		3	8		1
12/6	9	2	3	10	1	3	5	4	2
15/6	9	4	5	12	2	4	7	4	2
18/6	11	7	3	6	2	5	11	3	1
22/6	7	4	1	7	6	3	4	6	2
25/6	2	2	7	6	2	2	4	2	1
28/6	3	6	5	4	1	2	3		2
1/7		2	3		3	5		1	1
4/7		1	1		2			2	
7/7				1		2	1		1
10/7	2								1
16/7	2	1	1		2				
TOTAL	51	30	32	52	23	29	44	23	17
19/7	1						1	2	
24/7	2	1							
27/7	1			1				1	
30/7					1			3	
2/8	2	1		1					
5/8		2	1		1			3	
9/8				1	2	1	1		1
12/8	1							2	1
18/8				1	1	2	1	1	3
21/8		1	1	1	1	1		1	2
24/8	3		1	2				1	
27/8			1	2		1		1	2
30/8	1	4	3	2		6	2	1	1
15/9	3	7	1	4	2	5	5	4	9
18/9	6	7	4	5	13	3	1	4	9
21/9	12	4	3	6	8	2	1	6	4
TOTAL	32	27	15	26	29	21	12	30	32

TABLE 22. Amara spp.

	Con.			S.			SS.		
	C	E	H	A	D	I	B	F	G
22/5/66	1	1	2	1					
25/5		1							
28/5								1	
31/5	1							1	
3/6					1	2			
6/6			1	1		2			
9/6			1			1		1	
12/6		1	1						
15/6	1	1	1			1			
18/6		1						1	
22/6		1		2	1	1	1		
25/6		1				1		1	1
28/6	1	1	1	2			1		1
1/7			1				2		1
4/7		1			1		1	1	
7/7	4	1	3		1	1	3	1	
10/7	6	5	2		2	4	1	3	
16/7	4	6	4	2		3	4	2	
TOTAL	18	21	17	8	6	16	13	12	3
19/7	3		3		3	2	2	1	
24/7	1	2	3	3	2	3	2	1	
27/7	2	4	4		3	3	2	3	1
30/7	1	4	2	5	5		3	2	2
2/8	1	3	3	1	2	4	1	3	2
5/8	3		2		1	3		1	1
9/8	1	1	2	3	3	3	4	4	1
12/8	4	1	2	1	2	1		5	2
18/8	1		1	1	9	5		2	2
21/8		1	1		4	3	1		
24/8			1	3	1	1			
27/8				1	2	1			1
30/8		4	1	1		7		1	
15/9	1	1	1	1					
18/9	1		1			1			
21/9	1				1	2		1	
TOTAL	20	21	27	20	38	39	15	24	12

TABLE 23. L. pilicornis.

	Con.			S.			S.S.		
	C	E	H	A	D	I	B	F	G
22/5/66	2								
25/5	1								
28/5									
31/5			1						
3/6									
6/6					1				
9/6			1	1	1	1		1	
12/6	1		1			2			
15/6	1	1	1			1		2	
18/6	2	2	1	1	1		1	1	
22/6	3		1						
25/6		1						1	
28/6	4	1	1					1	
1/7	1						1		
4/7	1								
7/7					1				
10/7									
16/7			1						
TOTAL	16	5	8	2	4	4	2	6	0
19/7									
24/7			1					1	
27/7				1		1			
30/7	1			1			1	1	
2/8							1		
5/8									
9/8									
12/8									
18/8						1			
21/8									
24/8				1					
27/8	1					1			
30/8									
15/9	1								
18/9	3					1		1	
21/9		1	1		1				1
TOTAL	6	1	2	3	1	4	2	3	1

TABLE 24. Pterostichus spp.

	Con.			S.			S.S.		
	C	E	H	A	D	I	B	F	G
22/5/66	1				1			1	
25/5				1	1				1
28/5									
31/5									
3/6									
6/6							1		
9/6									
12/6			1			2			
15/6						4	1		
18/6			1	1	1	3	1		1
22/6									1
25/6				1	1		1		
28/6			1						
1/7			1		1				
4/7				1					
7/7			1						
10/7	1	1			1	2	1	2	1
16/7	1		2			1		2	1
TOTAL	3	1	7	4	6	12	5	5	5
19/7		1	1		1		1		
24/7								1	
27/7				1					3
30/7			1	1	1	1			1
2/8	1		2	2	1			1	
5/8			1						
9/8			2		1	1			
12/8		2			2		2	2	
18/8	3	3			5	2	3	1	2
21/8	1			1		1	2	1	
24/8	1			1	1		2	2	2
27/8		1	1		1	1	1	1	
30/8	1	1	1	1		1	1		
15/9		1						3	
18/9		1			3		1		
21/9		1							
TOTAL	7	11	9	7	16	7	13	12	8

TABLE 25. C. fossor.

	Con.			S.			S.S.		
	C	E	H	A	D	I	B	F	G
22/5/66	1		3						
25/5		2					1	1	
28/5	2	2						1	
31/5	1	1					1		1
3/6	3	1	1	2			3		
6/6	1					1			
9/6	1			1					
12/6		1					1	1	
15/6	1	1	1				1	1	1
18/6	1		1						
22/6	1		1		1	2			
25/6		2						1	
28/6									
1/7	1	1		2	1	1			
4/7						1		1	
7/7		2						1	1
10/7								1	
16/7				2	1		1		1
TOTAL	13	13	7	7	3	5	8	8	4
19/7	1			1					
24/7	1						2		1
27/7						1	1		
30/7		1					1	1	
2/8	1					1			
5/8									
9/8		1				1			
12/8	1								
18/8			1						
21/8				1					
24/8						1	1	1	
27/8			1						
30/8									
15/9								1	
18/9		1							
21/9				1	1				
TOTAL	4	3	2	3	1	4	5	3	1

TABLE 26. Calathus spp.

	Con.			S.			S.S.		
	C	E	H	A	D	I	B	F	G
22/5/66									
25/5									
28/5		1							
31/5									
3/6									
6/6									
9/6									
12/6									
15/6									
18/6									
22/6									
25/6									
28/6			1						
1/7									
4/7									
7/7									
10/7									
16/7							1		
TOTAL	0	1	1	0	0	0	1	0	0
19/7									
24/7									
27/7		1						1	
30/7			1		2				
2/8		1	1		1				
5/8									
9/8	1			1					
12/8		1		1					
18/8									
21/8									
24/8									
27/8									
30/8									
15/9									
18/9									
21/9									
TOTAL	1	3	2	2	3	0	0	1	0

TABLE 27. P. assimilis.

	Con.			S.			S.S.		
	C	E	H	A	D	I	B	F	G
22/5/66									
25/5									
28/5									
31/5									
3/6									
6/6									
9/6									
12/6									
15/6									
18/6									
22/6									
25/6									
28/6									
1/7									
4/7									
7/7									
10/7									
16/7									
19/7									
24/7									
27/7									
30/7									
2/8									
5/8									
9/8						1			
12/8							1		
18/8	3				1	1	2	1	
21/8	2				1	1	1	2	
24/8		1				1		2	
27/8	2					1			
30/8	1						1		
15/9				1					
18/9			1					1	
21/9	2	1					1	1	
TOTAL	10	2	1	1	2	5	6	7	0

TABLE 28. Notiophilus spp.

	Con.			S.			S.S.		
	C	E	H	A	D	I	B	F	G
22/5/66	1								
25/5									
28/5									
31/5	1						1		
3/6				1					
6/6			1						
9/6						1			
12/6									
15/6									
18/6					1				
22/6									
25/6									
28/6			1						
1/7									1
4/7									1
7/7									
10/7									
16/7									
TOTAL	2	0	2	1	1	1	1	0	2
19/7									
24/7									
27/7									
30/7	1								
2/8									2
5/8									
9/8									
12/8									
18/8									
21/8		1							
24/8									
27/8			1						
30/8					1				
15/9			1	1					
18/9									
21/9									
TOTAL	1	1	2	1	1	0	0	0	2

TABLE 29. Family Staphylinidae.

	Con.			S.			S.S.		
	C	E	H	A	D	I	B	F	G
22/5/66	20	17	14	15	6	14	17	25	15
25/5	13	11	13	8	6	7	9	6	7
28/5	12	29	17	5	19	25	15	30	25
31/5	25	29	25	12	9	14	21	19	20
3/6	35	36	25	6	6	7	22	19	12
6/6	34	27	25	14	10	24	21	33	7
9/6	8	19	33	11	8	3	7	24	12
12/6	26	19	18	5	9	10	10	11	15
15/6	11	13	5	3	2	8	1	9	1
18/6	3	1	3	1	6	1	1	0	0
22/6	7	5	14	3	2	6	5	4	3
25/6	8	10	6	1	1	1	3	9	4
28/6	10	6	7	5	5	4	6	12	9
1/7	11	7	3	4	3	1	6	7	4
4/7	9	6	5	3	2	3	6	4	8
7/7	13	10	8	10	4	4	9	10	5
10/7	7	10	11	9	5	0	6	4	5
16/7	3	5	4	4	7	3	6	5	9
TOTAL	255	260	236	119	110	135	171	231	161
19/7	6	12	13	4	2	0	12	6	17
24/7	5	8	11	5	5	3	9	5	10
27/7	6	9	13	4	6	5	9	3	13
30/7	7	9	10	4	3	6	9	4	6
2/8	6	7	2	4	3	5	6	9	7
5/8	2	5	3	5	2	2	5	4	5
9/8	3	3	4	5	8	5	14	5	6
12/8	2	13	5	4	6	2	7	8	6
18/8	1	2	9	4	16	8	12	5	18
21/8	4	5	4	6	7	5	7	1	4
24/8	2	6	4	2	3	8	5	3	5
27/8	5	3	4	4	8	10	3	4	8
30/8	4	6	1	6	9	2	0	5	12
15/9	1	1	0	1	3	0	3	0	4
18/9	0	0	0	2	1	2	1	0	0
21/9	0	0	3	2	1	0	4	0	5
TOTAL	54	89	86	62	83	63	106	62	126

TABLE 30. Atheta spp.

	Con.			S.			S.S.		
	C	E	H	A	D	I	B	F	G
22/5/66	15	14	10	12	4	12	13	21	11
25/5	7	9	7	5	3	3	8	3	5
28/5	7	19	16	4	13	18	10	19	15
31/5	10	11	12	9	5	5	10	8	9
3/6	25	23	15	1	2	3	12	16	7
6/6	28	19	15	13	6	17	17	26	7
9/6	2	8	13	11	6	2	3	19	7
12/6	22	14	12	2	8	8	8	10	13
15/6	10	10	2	3	2	6	1	8	1
18/6				1	3				
22/6		5	6	2	1	5	4	1	1
25/6		6			1	1	1	5	1
28/6	6	5	4	2	5	3	2	10	4
1/7	1	2			1		1	2	
4/7	2	2	1			1	2		1
7/7	9	4	4	8	3	2	6	10	3
10/7	6	8	5	5	3		2	2	2
16/7	3	3	0	2	6	1	3	4	3
TOTAL	153	162	122	80	72	87	103	164	90
19/7	4	6	4	1			3	2	3
24/7	4	4	3	3	2	2	5	2	4
27/7	2	5	3	3	2	4	4	3	4
30/7	3	7	3	2		1	5	1	4
2/8	4	5	2	4	1	5	3	7	5
5/8	2	4	3	5	2	1	4	2	2
9/8	1	1	2	5	7	4	14	4	4
12/8	2	7	4	3	6	2	7	4	3
18/8		1	3	4	13	7	12	5	15
21/8	4	3	4	6	6	5	6	1	4
24/8	2	4	4	2	2	7	5	2	3
27/8	4		3	3	6	8	3	3	6
30/8	3	4	1	5	9	2		5	12
15/9					3				4
18/9					1				
21/9							1		1
TOTAL	35	51	39	46	60	49	72	41	74

TABLE 31. O. rugosus

	Con.			S.			S.S.		
	C	E	H	A	D	I	B	F	G
22/5/66	2	1	1	2			1	1	
25/5	3		3	2		2	1		1
28/5	2	9			4	3	1	8	2
31/5	13	15	11	3	3	8	10	8	10
3/6	10	13	6	5	4	4	10	3	5
6/6	5	8	9	1	3	6	4	7	
9/6	6	9	19		2	1	3	4	4
12/6	4	5	5	2	1	2	2	1	2
15/6	1	2	3			2		1	
18/6	3	1	2		2	1	1		
22/6	7	5	5	1			1	2	2
25/6	2	2	4	1				2	2
28/6	4	1	2					1	4
1/7	2	3	3	1	1		3	4	4
4/7	2	3	4	1	1	1	2	2	6
7/7	2	5	3	2		2	1		2
10/7	1		4	3	2		1	1	1
16/7		2		2		1	1	1	3
TOTAL	69	84	84	26	23	33	42	46	48
19/7	2	5	8	2	2		8	3	12
24/7	1	2	6	2	2	1	3	3	5
27/7	4	3	3		3		4		4
30/7	5	2		2	2	1	4	3	2
2/8	1	2			1		2	1	
5/8			1			1	1	2	2
9/8	1	2	1			1		1	2
12/8		6	1					4	1
18/8			4		2	1			1
21/8		1							
24/8		2							
27/8		1		1	1	1		1	1
30/8		2							
15/9		1							
18/9									
21/9									
TOTAL	14	29	24	7	13	6	22	18	30

TABLE 32. L. longelytrata

	Con.			S.			S.S.		
	C	E	H	A	D	I	B	F	G
22/5/66	2	1	2			1	1	1	4
25/5	1	1	2			1			1
28/5	1	1		1	1	1	1	1	7
31/5		2				1		1	
3/6			2						
6/6									
9/6									
12/6									
15/6		1							
18/6									
22/6									
25/6		1							
28/6				1			3		
1/7									
4/7									
7/7									
10/7									
16/7									
TOTAL	4	7	6	2	1	4	5	3	12
19/7									
24/7									
27/7									
30/7									
2/8									
5/8									
9/8									
12/8									
18/8									
21/8									
24/8									
27/8									
30/8									
15/9									
18/9									
21/9									
TOTAL	0	0	0	0	0	0	0	0	0

TABLE 33. Philonthus spp.

	Con.			S.			S.S.		
	C	E	H	A	D	I	B	F	G
22/5/66	2		1				2	1	
25/5								2	
28/5	1				1				
31/5			2				1	1	
3/6			1						
6/6	1		1						
9/6									
12/6				1					
15/6									
18/6									
22/6									
25/6			1				1		
28/6				1		1			
1/7	5	2		3		1	1		
4/7	2	1			1	1	1	1	
7/7	1						1		
10/7			2	1					
16/7			2		1	1	1		
TOTAL	12	3	10	6	3	4	8	5	0
19/7									
24/7			2				1		1
27/7									
30/7			1						
2/8	1				1			1	1
5/8									
9/8			1		1				
12/8					1				2
18/8		1	1						1
21/8									
24/8					1				
27/8			1						
30/8	1								
15/9				1			2		
18/9						2			
21/9									
TOTAL	2	1	6	1	4	2	3	1	5

TABLE 34. T. rufipes

	Con.			S.			S.S.		
	C	E	H	A	D	I	B	F	G
22/5/66	1	1		1	2	1		1	
25/5	2	1		1	3	1		1	
28/5	1		1	1		3	3	2	1
31/5	1	1			1			1	1
3/6			1						
6/6						1			
9/6		2							1
12/6			1						
15/6									
18/6					1				
22/6			2			1			
25/6		1	1				1		1
28/6				1			1	1	1
1/7	3							1	
4/7	1			1			1	1	1
7/7		1							
10/7		2					1		
16/7									
TOTAL	9	9	6	5	7	7	7	8	6
19/7			1	1					1
24/7					1				
27/7				1	1				
30/7									
2/8									
5/8									
9/8									
12/8									
18/8									
21/8									
24/8									
27/8		1							1
30/8				1					
15/9									
18/9									
21/9									
TOTAL	0	1	1	3	2	0	0	0	2

TABLE 35. Tachyporus spp.

	Con.			S.			S.S.		
	C	E	H	A	D	I	B	F	G
22/5/66									
25/5									
28/5									
31/5	1								
3/6									
6/6									
9/6			1					1	
12/6									
15/6									
18/6									
22/6			1		1			1	
25/6									
28/6									
1/7					1		1		
4/7	2			1					
7/7			1		1		1		
10/7								1	
16/7							1		
TOTAL	3	0	3	1	3	0	3	3	0
19/7		1					1		1
24/7		1							
27/7			3			1			
30/7			3		1	3			
2/8									
5/8		1							1
9/8									
12/8									
18/8									
21/8							1		
24/8							1		
27/8									
30/8									
15/9									
18/9									
21/9									
TOTAL	0	3	6	0	1	4	3	0	2

APPENDIX III

Cabbage root fly eggs and chorions sampled from plants with and without barriers (one of each per plot) in the two diazinon treatments and the control during 1965.

TABLE 36. Total full eggs + empty chorions (with barriers)

	Con.			S.			S.S.		
	C	D	G	A	F	I	B	E	H
1/6/65	1	0	2	38	10	24	16	15	19
4/6	3	11	22	18	71	23	40	3	32
10/6	9	83	23	13	41	34	10	55	30
13/6	32	21	10	11	56	31	5	52	38
16/6	31	17	4	17	73	8	99	6	42
19/6	4	4	5	17	0	9	2	1	61
22/6	5	8	5	1	4	38	0	17	16
25/6	25	18	2	3	44	49	14	16	33
28/6	41	24	2	16	9	25	48	3	13
1/7	3	2	27	6	24	13	34	4	17
4/7	8	15	11	11	7	10	30	3	8
7/7	20	37	1	1	0	17	28	19	9
11/7	17	30	27	6	29	110	7	12	9
13/7	38	22	12	10	4	1	19	16	39
16/7	8	5	27	4	9	13	16	21	6
22/7	11	6	14	4	6	18	23	3	27
TOTAL	256	303	194	176	387	423	391	246	399
3/8	2	4	0	0	2	25	0	15	0
6/8	0	4	14	3	2	61	3	6	24
9/8	49	23	11	1	70	1	4	0	13
12/8	8	10	9	0	10	10	5	23	25
15/8	42	0	6	20	49	19	14	0	1
18/8	16	46	2	18	7	16	36	1	15
24/8	71	32	18	2	4	8	16	5	27
27/8	39	48	12	22	56	1	18	2	3
30/8	20	0	6	11	47	3	12	0	10
2/9	9	0	9	3	12	0	1	3	4
5/9	7	18	1	10	0	14	2	23	4
8/9	2	0	7	2	2	13	1	3	15
14/9	5	3	1	0	1	3	9	0	0
17/9	1	4	3	4	2	3	5	0	7
20/9	9	7	20	9	3	6	0	10	7
TOTAL	280	199	119	105	267	183	126	91	155

TABLE 37. Full eggs (with barriers)

	Con.			S.			S.S.		
	C	D	G	A	F	I	B	E	H
1/6/65	0	0	2	21	1	0	0	10	15
4/6	1	0	2	13	70	22	33	2	13
10/6	6	45	20	5	30	17	6	22	21
13/6	15	9	3	6	54	28	0	24	23
16/6	15	10	3	14	29	7	37	0	19
19/6	0	1	3	4	0	2	0	0	26
22/6	1	1	0	1	1	10	0	3	0
25/6	20	0	0	0	27	22	0	2	2
28/6	10	0	1	4	5	7	39	0	0
1/7	0	0	1	2	7	0	3	0	0
4/7	0	0	10	1	0	3	10	0	0
7/7	19	0	0	0	0	0	28	0	0
11/7	2	14	7	0	24	21	0	11	0
13/7	0	0	0	0	0	1	0	0	13
16/7	1	3	0	0	0	0	0	1	0
22/7	1	0	5	3	0	0	7	0	0
TOTAL	91	83	57	74	248	140	163	75	132
3/8	2	0	0	0	0	0	0	1	0
6/8	0	0	1	0	0	56	0	0	0
9/8	14	0	0	0	46	0	0	0	0
12/8	0	10	0	0	9	0	5	19	2
15/8	23	0	6	0	25	14	0	0	0
18/8	0	2	0	1	7	0	2	0	1
24/8	17	1	0	0	0	0	1	0	6
27/8	8	11	0	0	17	0	12	0	0
30/8	13	0	0	0	19	0	0	0	0
2/9	0	0	0	0	1	0	1	0	0
5/9	0	0	0	0	0	0	0	0	0
8/9	0	0	0	0	0	0	0	0	0
14/9	0	0	0	0	1	0	0	0	0
17/9	0	0	0	0	0	0	0	0	0
20/9	0	0	0	0	0	0	0	0	0
TOTAL	77	24	7	1	125	70	21	20	9

TABLE 38. Viable eggs (with barriers)

	Con.			S.			S.S.		
	C	D	G	A	F	I	B	E	H
1/6/65	1	0	2	12	1	10	10	8	10
4/6	0	0	2	13	53	10	30	2	4
10/6	4	43	19	3	6	8	4	18	20
13/6	12	7	2	3	39	19	0	22	18
16/6	15	10	3	9	25	7	32	0	16
19/6	0	1	3	0	0	0	0	0	20
22/6	1	1	0	0	0	10	0	2	0
25/6	17	0	0	0	5	17	0	0	0
28/6	8	0	1	0	5	3	35	0	0
1/7	0	0	0	2	4	0	2	0	0
4/7	0	0	8	0	0	0	6	0	0
7/7	18	0	0	0	0	0	18	0	0
11/7	1	14	6	0	24	17	0	11	0
13/7	0	0	0	0	0	1	0	0	12
16/7	1	3	0	0	0	0	0	0	0
22/7	0	0	5	2	0	0	5	0	0
TOTAL	78	79	51	44	162	102	142	63	100
3/8	2	0	0	0	0	0	0	1	0
6/8	0	0	1	0	0	52	0	0	0
9/8	9	0	0	0	45	0	0	0	0
12/8	0	10	0	0	9	0	5	18	2
15/8	21	0	4	0	20	14	0	0	0
18/8	0	0	0	1	7	0	0	0	1
24/8	2	0	0	0	0	0	0	0	1
27/8	7	11	0	0	16	0	11	0	0
30/8	8	0	0	0	19	0	0	0	0
2/9	0	0	0	0	0	0	0	0	0
5/9	0	0	0	0	0	0	0	0	0
8/9	0	0	0	0	0	0	0	0	0
14/9	0	0	0	0	1	0	0	0	0
17/9	0	0	0	0	0	0	0	0	0
20/9	0	0	0	0	0	0	0	0	0
TOTAL	49	21	5	1	117	66	16	19	4

TABLE 39. Total full eggs + empty chorions (without barriers)

	Con.			S			S.S.		
	C	D	G	A	F	I	B	E	H
1/6/65	4	2	0	3	1	8	5	5	0
4/6	1	5	1	6	12	26	1	8	1
10/6	9	9	6	24	3	41	20	46	14
13/6	20	28	2	28	26	24	11	3	5
16/6	4	9	5	45	19	12	5	11	8
19/6	2	19	14	16	8	7	33	9	2
22/6	11	2	21	1	24	26	7	29	8
25/6	6	15	6	4	20	0	12	0	9
28/6	9	6	39	17	3	9	23	8	6
1/7	1	1	8	14	13	4	47	1	4
4/7	39	2	0	5	11	18	32	18	2
7/7	25	10	6	0	33	6	1	1	9
11/7	0	12	18	17	0	4	10	3	19
13/7	26	18	9	2	7	4	14	1	3
16/7	21	16	2	1	0	7	16	4	0
22/7	17	4	14	0	8	0	1	2	0
TOTAL	195	158	151	183	188	196	238	149	90
3/8	0	10	5	2	19	0	16	2	0
6/8	11	5	6	2	20	3	7	0	11
9/8	3	5	13	0	13	19	29	0	1
12/8	4	4	5	7	19	22	1	1	1
15/8	1	14	28	1	6	11	0	4	4
18/8	51	44	20	7	6	3	9	8	0
24/8	0	0	11	11	16	0	12	6	15
27/8	25	20	14	61	26	5	2	13	0
30/8	6	5	6	12	6	5	3	1	0
2/9	12	39	0	10	6	4	2	3	0
5/9	15	0	0	1	0	2	0	5	23
8/9	0	3	6	6	2	23	5	0	17
14/9	0	6	0	5	7	0	0	0	2
17/9	1	0	7	12	6	0	0	2	4
20/9	31	11	1	3	14	4	0	6	15
26/9	0	0	0	4	0	1	0	1	9
TOTAL	160	166	122	144	166	102	86	52	102

TABLE 40. Full eggs (without barriers)

	Con.			S.			S.S.		
	C	D	G	A	F	I	B	E	H
1/6/65	4	2	0	3	0	4	4	3	0
4/6	1	1	1	5	12	26	0	8	0
10/6	5	7	4	6	3	34	0	31	8
13/6	8	13	2	9	25	23	10	2	3
16/6	1	1	5	21	17	10	3	1	4
19/6	1	8	2	3	8	4	14	4	2
22/6	8	0	1	0	13	5	1	1	2
25/6	0	3	1	0	20	0	0	0	6
28/6	1	3	9	9	0	3	6	0	3
1/7	0	0	5	3	0	0	3	0	0
4/7	1	0	0	1	10	2	20	0	0
7/7	7	0	0	0	4	1	0	0	0
11/7	0	3	0	2	0	0	0	0	1
13/7	0	0	1	0	4	0	13	0	0
16/7	0	0	0	0	0	0	0	0	0
22/7	9	0	0	0	0	0	0	0	0
TOTAL	46	41	31	62	116	112	74	50	29
3/8	0	1	0	0	11	0	0	2	0
6/8	1	0	2	0	12	0	0	0	0
9/8	3	2	12	0	0	7	29	0	0
12/8	0	0	0	4	5	1	0	0	0
15/8	0	8	7	0	0	8	0	0	2
18/8	5	24	3	7	0	0	1	1	0
24/8	0	0	0	8	7	0	0	2	1
27/8	8	1	8	9	5	0	0	1	0
30/8	1	1	0	0	0	1	3	0	0
2/9	1	2	0	0	1	0	0	1	0
5/9	1	0	0	0	0	1	0	0	0
8/9	0	0	0	1	0	0	0	0	8
14/9	0	0	0	0	0	0	0	0	0
17/9	0	0	0	0	0	0	0	0	0
20/9	0	1	0	0	0	0	0	0	0
26/9	0	0	0	0	0	0	0	0	0
TOTAL	20	40	32	29	41	18	33	7	11

TABLE 41. Viable eggs (without barriers)

	Con.			S.			S.S.		
	C	D	G	A	F	I	B	E	H
1/6/65	4	2	0	2	0	4	4	1	0
4/6	1	1	1	5	1	25	0	8	0
10/6	4	6	2	5	2	14	16	26	4
13/6	8	13	2	3	16	7	9	1	2
16/6	1	1	4	14	7	6	2	0	2
19/6	1	8	2	2	5	3	12	3	2
22/6	8	0	0	0	8	0	0	0	2
25/6	0	3	0	0	15	0	0	0	6
28/6	0	2	7	9	0	2	3	0	3
1/7	0	0	5	0	0	0	2	0	0
4/7	0	0	0	0	9	2	20	0	0
7/7	7	0	0	0	3	0	0	0	0
11/7	0	2	0	1	0	0	0	0	0
13/7	0	0	0	0	2	0	13	0	0
16/7	0	0	0	0	0	0	0	0	0
22/7	8	0	0	0	0	0	0	0	0
TOTAL	42	38	23	41	68	63	65	39	21
3/8	0	1	0	0	7	0	0	2	0
6/8	1	0	1	0	9	0	0	0	0
9/8	3	2	11	0	0	6	29	0	0
12/8	0	0	0	4	5	0	0	0	0
15/8	0	6	3	0	0	7	0	0	2
18/8	4	24	0	7	0	0	0	0	0
24/8	0	0	0	8	7	0	0	2	0
27/8	7	0	1	4	0	0	0	0	0
30/8	1	1	0	0	0	1	2	0	0
2/9	0	1	0	0	0	0	0	0	0
5/9	0	0	0	0	0	1	0	0	0
8/9	0	0	0	0	0	0	0	0	7
14/9	0	0	0	0	0	0	0	0	0
17/9	0	0	0	0	0	0	0	0	0
20/9	0	0	0	0	0	0	0	0	0
26/9	0	0	0	0	0	0	0	0	0
TOTAL	16	35	16	23	28	15	31	4	9

APPENDIX IV

Cabbage root fly eggs and chorions sampled from plants with and without barriers (two of each per plot) in the two chlorfenvinphos treatments and the control during 1966.

TABLE 42. Total full eggs + empty chorions (with barriers)

	Con.			S.			S.S.		
	C	E	H	A	D	I	B	F	G
26/5/66	0	4	0	2	0	0	8	0	0
29/5	4	10	24	4	11	18	1	15	7
1/6	57	12	32	15	4	21	28	27	6
4/6	40	29	19	60	35	81	38	70	59
7/6	34	44	86	19	13	77	43	80	40
10/6	57	32	42	28	86	46	29	55	54
13/6	42	28	63	70	23	80	60	85	122
16/6	146	111	70	78	83	118	65	40	45
19/6	131	55	65	114	43	133	102	77	85
22/6	76	26	37	39	145	45	56	87	98
25/6	35	52	38	39	126	79	42	67	62
28/6	73	48	54	53	56	49	55	63	23
1/7	46	71	31	37	27	56	39	15	29
4/7	33	22	26	9	16	32	6	11	39
7/7	18	9	14	8	38	12	10	9	21
10/7	34	11	16	14	18	22	5	16	9
13/7	7	11	11	6	11	19	22	13	12
16/7	7	8	4	8	15	6	2	4	6
TOTAL	840	583	632	603	750	894	611	734	717
21/7	7	6	8	6	5	2	6	2	2
24/7	21	10	5	16	21	22	17	15	6
27/7	18	15	12	6	45	26	46	6	24
30/7	50	1	11	18	5	7	19	1	5
2/8	44	83	29	4	0	41	55	15	31
5/8	18	35	26	16	7	25	4	2	6
8/8	14	8	17	2	29	32	14	18	13
12/8	9	41	8	13	26	40	31	3	8
15/8	9	9	7	2	2	6	21	0	7
18/8	6	5	17	3	9	0	2	3	3
23/8	7	5	2	2	3	0	3	4	7
26/8	0	0	2	4	0	3	0	8	5
TOTAL	203	218	144	92	152	204	218	77	117

TABLE 43. Full Eggs (with barriers)

	Con.			S.			S.S.		
	C	E	H	A	D	I	B	F	G
26/5/66	0	3	0	2	0	0	8	0	0
29/5	4	10	23	4	11	18	1	14	7
1/6	57	12	30	15	4	21	28	23	5
4/6	39	13	17	59	35	80	38	67	51
7/6	24	32	39	19	12	60	40	45	25
10/6	26	12	3	27	85	46	17	11	27
13/6	9	9	17	70	14	80	45	55	37
16/6	69	61	40	77	75	115	34	29	34
19/6	28	29	13	67	32	128	46	53	48
22/6	20	6	2	37	141	42	41	15	78
25/6	7	15	13	38	103	68	15	18	39
28/6	10	15	11	48	51	36	14	2	13
1/7	5	20	0	32	25	47	7	3	12
4/7	1	0	8	7	12	25	0	0	12
7/7	0	1	2	6	20	9	1	0	0
10/7	1	2	1	5	6	5	1	0	1
13/7	0	2	1	5	7	8	1	0	3
16/7	0	0	1	5	3	2	1	0	0
TOTAL	300	242	221	523	636	790	338	335	392
21/7	0	2	0	5	2	0	0	0	0
24/7	0	0	0	3	8	0	6	0	0
27/7	0	5	7	1	1	19	10	0	8
30/7	13	0	9	1	3	1	1	0	5
2/8	16	21	22	0	0	29	34	9	3
5/8	2	8	10	2	3	5	0	1	3
8/8	0	4	2	2	10	7	0	6	2
12/8	0	37	0	13	26	10	11	0	7
15/8	0	9	2	2	0	2	15	0	4
18/8	5	0	6	0	2	0	0	3	0
23/8	0	0	0	0	1	0	0	0	0
26/8	0	0	0	0	0	0	0	0	0
TOTAL	36	86	58	29	56	73	77	19	32

TABLE 44. Viable eggs (with barriers)

	Con.			S.			S.S.		
	C	E	H	A	D	I	B	F	G
26/5/66	0	3	0	0	0	0	8	0	0
29/5	4	10	22	3	10	14	1	11	7
1/6	52	11	24	13	3	10	27	21	5
4/6	36	10	14	46	30	58	29	62	46
7/6	24	26	34	6	5	25	32	45	18
10/6	26	9	3	7	15	5	16	11	23
13/6	9	8	17	1	2	17	32	40	24
16/6	65	60	38	13	7	14	19	19	31
19/6	24	26	9	19	19	28	32	34	32
22/6	20	5	1	8	24	24	39	13	64
25/6	6	15	12	19	27	23	11	15	34
28/6	6	15	10	24	25	16	10	0	5
1/7	4	20	10	2	11	0	7	2	10
4/7	0	0	8	2	7	0	0	0	11
7/7	0	0	2	0	1	0	1	0	0
10/7	0	0	1	0	1	0	0	0	0
13/7	0	2	0	0	1	0	0	0	3
16/7	0	0	1	0	0	0	1	0	0
TOTAL	276	220	206	163	188	234	265	273	313
21/7	0	2	0	0	0	0	0	0	0
24/7	0	0	0	3	2	0	6	0	0
27/7	0	5	5	1	1	10	10	0	8
30/7	13	0	8	1	2	1	1	0	5
2/8	16	16	21	0	0	17	31	9	3
5/8	2	8	6	2	2	4	0	1	3
8/8	0	4	2	2	6	7	0	5	2
12/8	0	36	0	13	25	8	10	0	7
15/8	0	9	2	2	0	0	15	0	2
18/8	5	0	5	0	2	0	0	3	0
23/8	0	0	0	1	0	0	0	0	0
26/8	0	0	0	0	0	0	0	0	0
TOTAL	36	80	49	25	40	47	73	18	30

TABLE 45. Total full eggs + empty chorions (without barriers)

	Con.			S.			S.S.		
	C	E	H	A	D	I	B	F	G
26/5/66	0	1	0	4	0	0	0	0	1
29/5	5	2	6	22	12	12	0	25	3
1/6	47	30	18	12	14	33	5	4	17
4/6	28	61	51	17	40	65	51	51	11
7/6	11	34	39	16	16	24	56	100	31
10/6	27	16	7	83	92	43	31	15	31
13/6	52	40	52	26	75	33	10	29	74
16/6	110	81	4	46	57	81	47	57	27
19/6	55	55	59	68	38	87	33	21	19
22/6	29	58	45	10	135	50	36	54	38
25/6	38	12	46	22	74	41	15	55	21
28/6	16	33	43	26	49	33	20	14	51
1/7	25	6	26	28	24	19	8	28	25
4/7	12	25	18	16	31	19	0	25	20
7/7	33	3	9	9	25	18	0	21	17
10/7	5	9	9	11	0	11	22	13	28
13/7	1	10	4	11	7	7	1	10	2
16/7	8	1	0	9	5	2	5	2	8
TOTAL	502	477	436	436	694	578	340	524	424
21/7	12	1	11	2	7	18	9	2	4
24/7	7	9	11	18	7	20	11	6	4
27/7	23	18	6	12	10	23	21	14	2
30/7	19	4	33	15	25	1	3	0	9
2/8	31	19	2	24	2	26	17	6	18
5/8	3	0	26	29	5	2	6	0	18
8/8	22	6	13	1	8	10	8	8	3
12/8	7	3	10	13	5	6	17	25	14
15/8	14	1	3	8	9	19	4	17	6
18/8	0	4	10	11	9	7	8	16	1
23/8	3	7	0	1	7	1	1	0	2
26/8	4	6	0	3	0	5	0	0	0
TOTAL	145	78	125	137	94	138	105	94	81

TABLE 46. Full eggs (without barriers)

	Con.			S.			S.S.		
	C	E	H	A	D	I	B	F	G
26/5/66	0	1	0	4	0	0	0	0	1
29/5	5	2	6	22	12	12	0	25	3
1/6	47	24	18	12	14	33	5	3	17
4/7	27	52	35	16	37	56	51	45	8
7/6	10	25	14	14	16	20	56	38	29
10/6	5	4	1	79	91	42	17	8	17
13/6	13	21	8	25	66	20	3	11	34
16/6	54	41	1	46	57	73	26	50	11
19/6	20	26	33	61	22	78	33	8	5
22/6	0	15	23	10	96	35	12	22	17
25/6	8	1	25	22	64	27	5	20	8
28/6	4	7	24	20	41	26	4	2	19
1/7	4	5	3	23	14	17	7	5	9
4/7	0	4	3	14	16	9	0	2	4
7/7	1	1	1	5	9	13	0	1	2
10/7	1	0	4	4	0	3	0	7	6
13/7	1	0	0	2	4	2	0	0	0
16/7	0	0	0	1	2	1	0	0	1
TOTAL	200	229	199	380	561	467	219	247	191
21/7	0	0	0	2	1	5	3	0	0
24/7	1	3	0	4	0	5	0	0	0
27/7	6	1	0	0	2	2	6	9	0
30/7	10	0	3	13	12	0	1	0	2
2/8	10	14	2	24	1	20	4	0	13
5/8	0	0	24	24	0	0	1	0	1
8/8	1	1	0	0	1	2	2	1	0
12/8	7	0	6	3	1	6	6	5	9
15/8	4	0	1	4	1	3	0	15	5
18/8	0	2	4	2	3	0	7	9	0
23/8	0	0	0	0	1	1	0	0	0
26/8	0	0	0	0	0	0	0	0	0
TOTAL	39	21	40	76	23	44	30	39	30

TABLE 47. Viable eggs (without barriers)

	Con.			S.			S.S.		
	C	E	H	A	D	I	B	F	G
26/5/66	0	1	0	2	0	0	0	0	1
29/5	3	2	6	21	10	4	0	21	3
1/6	46	21	18	11	10	25	4	3	15
4/6	24	51	34	9	26	48	41	44	5
7/6	10	22	14	11	6	3	53	27	26
10/6	5	4	1	22	20	7	11	7	13
13/6	11	20	4	1	42	10	0	11	19
16/6	53	39	1	18	16	41	8	42	10
19/6	18	21	31	21	10	17	18	7	3
22/6	0	10	17	5	57	12	12	18	16
25/6	8	1	24	3	26	6	5	16	8
28/6	4	6	22	3	5	4	4	2	18
1/7	3	5	3	4	3	0	7	2	0
4/7	0	3	3	8	0	3	0	2	4
7/7	1	1	0	0	1	0	0	0	2
10/7	0	0	4	0	0	0	0	6	6
13/7	1	0	0	0	0	0	0	1	0
16/7	0	0	0	0	0	0	0	0	1
TOTAL	187	207	182	139	232	180	163	209	150
21/7	0	0	0	0	0	0	3	0	0
24/7	1	3	0	0	0	5	0	0	0
27/7	6	1	0	0	2	1	6	8	0
30/7	10	0	0	13	9	0	1	0	2
2/8	10	14	2	15	1	20	4	0	13
5/8	0	0	24	17	0	0	0	0	0
8/8	1	1	0	0	1	2	2	0	0
12/8	7	0	5	2	0	5	6	4	9
15/8	4	0	1	4	1	3	0	14	4
18/8	0	0	4	2	2	0	7	7	0
23/8	0	0	0	0	1	1	0	0	0
26/8	0	0	0	0	0	0	0	0	0
TOTAL	39	19	36	53	17	37	29	33	28

APPENDIX V

E. brassicae and I. rapae adults captured in the emergence cages in the field.

TABLE 48. E. brassicae first generation

Date	Cage number																	
	1			2			3			4			5			6		
	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c
17/5/66	1									1								
18/5														1				
19/5	2			1	1					2	1							
20/5									1	1	1			2	1	1		
21/5					2	1				1								
22/5	1	1								1			1					2
23/5		2			1											1	1	
24/5							1		2									
25/5							1								1			
26/5																		
27/5				1														
28/5		1																
1/6											1							
3/6											1							
10/6																1		
TOTAL	4	4	0	2	4	1	2	0	3	6	4	0	1	3	2	3	1	2

a = E. brassicae males.

b = E. brassicae females.

c = I. rapae.

TABLE 49. E. brassicae second generation

Date	Cage number																	
	1			2			3			4			5			6		
	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c
20/7/66	1						1	1					2					
21/7	2						2	1					1				1	
22/7							1	1		1			1	3		1		
23/7								1			1		1				1	
24/7						1				2	1		1	1				
25/7		1							1	1				1				
26/7														2				
27/7						1										1		
28/7							1											
29/7										1		1					1	1
30/7				1														
1/8				1														
7/8				1														
12/8						2												
14/8		1																
15/8		1																
TOTAL	3	3	0	3	0	4	5	4	1	5	2	1	6	7	0	2	3	1

a = E. brassicae males.

b = E. brassicae females

c = I. rapae