PESTS OF RHODODENDRONS IN BRITAIN WITH SPECIAL

REFERENCE TO THE WEEVIL OTIORHYNCHUS SINGULARIS (L.).

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BY

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CONTAINS

PULLOUTS

ABSTRACT

The principal rhododendron pests of Great Britain are described; these comprise Rhododendron Whitefly, _Dialeurodes chittendeni_ Laing; Rhododendron Bug, _Stephanitis rhododendri_ Horvath; Rhododendron Leaf-hopper, _Graphocephala coccinea_ (Forst.); Azalea Whitefly, _Aleurodes azaleae_ Baker and Moles; Clay coloured Weevil, _Otiorhynchus singularis_ (L); and the tortricid moth, _Tortrix viridana_ (L.).

The first four mentioned pests have a restricted distribution mainly in the south of England and have not spread to other parts of the country during the past thirty years, but there are fears that they may become established in some of the warmer parts of the British Isles in the near future.

The last two pests appear to be more common on rhododendron than previously.

Some pests including aphids, nematodes, slugs and certain Lepideptera and Coleoptera are mentioned, as are pests found in the U.S.A. and other parts of the world. A key to damage caused by insects on rhododendrons has been produced.

A more detailed description is given of _Otiorhynchus singularis_, together with the results of experiments on the effects of humidity, temperature, light and food on the oviposition,

feeding habits and longevity of the adult weevil.

Humidity was found to have a great effect on the life span, oviposition and eating habits, a high humidity being favourable to the weevils. A high temperature increased egg laying and the amount of food eaten, but reduced longevity. The presence or absence of food and light were not significant factors.

Comparisonsof some British species of Otiorhynchinae are made, and a new simple key to the imagines is given.

A brief description is provided of the parasite Pygostolus sticticus (Fab.), a new record as a parasite on O. singularis.

ACKNOWLEDGEMENTS.

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PART II

INTRODUCTION

It is now over 30 years since Fox Wilson read a paper to the International Congress for Entomology on the Insect Pests of the Genus Rhododendron. Since that time new pests have been discovered throughout the world, others which were troublesome have now been almost eliminated by modern chemical insecticides. The status of several of the pests has altered and this research has been carried out to discover what are the present pests on rhododendrons.

Some pests are still present locally where rhododendrons are grown in any numbers, but do not appear to be spreading to other areas. These include the endemic ones such as Rhododendron Whitefly, Rhododendron Bug and Rhododendron Leafhopper. Other insects, for instance the clay coloured weevil and the Tortrix moth, have now adopted the rhododendron as one of their host plants and can be found almost anywhere rhododendrons are grown.

Rhododendrons need a low alkaline content and/^{low}pH in the soil, otherwise the uptake of iron is insufficient for their healthy growth. Since the advent of sequestrinated iron compounds, which can be watered on to the soil around the plants allowing iron molecules to be freed, more rhododendrons have been grown. This is particularly so in the south of England where rhododendrons, including azaleas, are now some of the most popular spring shrubs. This has meant that in recent years more horticultural nurserymen have been propagating and growing rhododendrons and in my visits to commercial growers of these

plants I have found a serious lack of knowledge about the pests causing damage to their young plants and therefore the pests are not always recognised, sprayed or collected at the correct time and so controlled.

The following thesis should prove to be of use to growers of outdoor rhododendrons. Although outlines of the life histories and the morphology of the mentioned important pests are written down and much research has been done into their history and the literature, the more precise entomological details are not always given.

In the case of <u>Otiorhynchus singularis</u> L., a widespread pest of many garden plants besides the rhododendron, more details are supplied and several experiments have been performed. A full description of the work carried out on this insect will form a separate section of the thesis.

OCCURRENCE OF INSECT PESTS ON OUTDOOR RHODODENDRONS

IN GREAT BRITAIN

The major pests of rhododendrons are in the Order Hemiptera. In Great Britain these occur only in the south of England and very occasionally in some other counties of England and Scotland. (The maps accompanying the description of each pests show their individual distribution). When imported on to plants in Keele, Staffordshire, the hemipterous pests died out in less than a year. Most of these insects are endemic on the rhododendron and include the Rhododendron Whitefly (Dialeurodes chittendeni Laing), the Rhododendron Bug (Stephanitis rhododendri Horv.), the Rhododendron Leafhopper (Graphocephala coccinea L.(Forst.)), and the Azalea Whitefly (Aleurodes azaleae Baker and Moles). The above will be described individually, but others, including Aphis spp., which are not so troublesome on the rhododendron, will only be mentioned.

In contrast to those in the above Order, the insect pests of the Order Coleoptera are to be found not only on other plants besides the rhododendron, but also all over the British Isles. They are also widespread in Europe. The Clay-coloured weevil (Otiorhynchus singularis(L.)) was the most frequent pest on rhododendrons in Staffordshire whilst I was carrying out investigations there 1962-65, and the damage is commonly seen on rhododendrons in most areas. Vine weevil (Otiorhynchus sulcatus(Fab.)) and the Cockchafer beetle or Maybug (Melolontha melolontha (L.)) are fairly common, the latter more so in some years than others. The Nut Leaf Weevil (Strophosomus melanogrammus(Forst.)), although not

a serious pest, is widely spread.   The small chafer (<u>Serica brunnea</u>(L.)),
I have found only in Staffordshire and it has not previously been record-
ed as damaging rhododendrons, but from damage seen elsewhere I suspect
that it may be widely distributed.

Damage by lepidopterous caterpillars is commonly seen on
rhododendron leaves throughout the British Isles, mostly on the varie-
ties of plants having a thick, hairy indumentum on their leaves.   Many
of the bushes so attacked are under oak trees in wooded areas, but
plants not directly under the trees are also eaten.   The presence of
an indumentum appears to be more relevant than the proximity of the
bushes to the trees.   The <u>Tortrix</u> species are the ones causing most
damage.

In the Order Hymenoptera, the insects causing damage are
not serious pests.   The leaf-cutting bee <u>Megachile sp.</u> sometimes uses
semicircles from a rhododendron leaf, but this is not serious or common.
I have twice found sawfly larvae on <u>R. ponticum</u> in Staffordshire, but
they are so far unidentified (Plate 23).

Also in the Hymenoptera is a parasitic brachonid wasp,
<u>Pygostolus stictious</u>(F.), which has been discovered by the author to be
an internal parasite of the Clay-coloured weevil, <u>O. singularis</u>.
Because this is a biological control of one of the rhododendron pests
and as its host was before unknown, a separate chapter has been devoted
to <u>P. stictious</u>.

THE IMPORTANCE OF RHODODENDRON PESTS IN GREAT BRITAIN;

THEIR GENERAL DAMAGE AND CONTROL

The actual form of the damage and the specific control of each pest will be found under the separate headings of the individual pest. Here the overall damage to rhododendrons and the possibilities of controlling the pests will be assessed.

Most of the damage by pests of outdoor rhododendrons, which are particularly hardy plants, appears as unsightliness and a weakening of the shrub, rather than actual death of the plant. In very small plants and rooted cuttings, however, the damage may prove fatal, as I have observed in the case of young plants attacked by Otiorhynchus singularis, O. sulcatus or Strophosomus melanogrammus. Shrubs attacked by Graphocephala coccinea, and therefore liable to be attacked by the Bud Blast disease, may lose so many buds from the fungus attack that the plant may weaken and die.

Older plants can usually grow away after leaf damage, but the unsightly foliage may prove to be a great disadvantage to a nurseryman offering the plants for sale. Also these nursery plants are usually small and pest damage is more noticeable than on established shrubs.

With modern insecticides and mechanical and cultural controls, all the pests mentioned can be dealt with and kept under control where necessary.

Where rhododendrons are naturalised in a woodland, no

chemical control is recommended, but it may be necessary in the commercial nursery and occasionally in the public park and private garden.

The coleopterous and lepidopterous pests of the rhododendron in Great Britain attack other garden plants also, and for this reason they may have to be controlled.

Plate 1.

ELDSWOOD, WILLOUGHBRIDGE, STAFFORDSHIRE

Most of the observations on the outdoor rhododendrons in the north of England were made in the garden of Colonel Harry Clive at Willoughbridge, a hamlet on the Market Drayton road, seven miles from the University of Keele, Staffordshire.

Before listing and discussing the pests found, I think it appropriate here to write something of the position, the climate and the history of Eldswood, Willoughbridge.

Geographically, the Willoughbridge garden lies almost at a point where Staffordshire, Shropshire and Cheshire meet. The soil is sandy and the pH of the soil is very low, 4 to 4.5; therefore only the acid-loving shrubs survive.

The garden is too far north for many of the Rhododendron pests to affect the plants, and the climate is rather cold, often wet and windy.

Because of the informal, semi-wildness of the arrangement, no set, formal experiments were carried out at Willoughbridge, but many observations were made and insects collected all the year round, both during the day and during the hours of darkness.

This rhododendron garden was formerly a gravel pit, and after working had discontinued there, an oak wood evolved. The wood had been partially cleared thirty years before and a great number of rhododendron hybrids and species, including hundreds of azaleas, had been planted.

The two photographs show the Eldswood garden in May 1964.
The steep sloping side of the quarry can clearly be seen (Plates 1 and 2).

The more formal experiments were carried out in the grounds
and laboratories of the Department of Biology, University of Keele,
Staffordshire.

Plate 2.

Eldswood, Willoughbridge.

Plate 2.

LISTS OF SMALL ANIMALS FOUND ON OR UNDER RHODODENDRON BUSHES.

TABLE (1). ANIMALS EXTRACTED FROM SOILS AROUND RHODODENDRON
BUSHES AT KEELE AND WILLOUGHBRIDGE

These were extracted by methods described under the section on O. singularis (p.138).

The soil was very acid, pH 4.1, rich in both available phosphate and potash, but with smaller amounts of available nitrates and iron. It was often little more than decayed bracken and oak leaves over gravel and sand.

Class or order	Name	Remarks	Depth
Nematoda	Xiphenima sp. / Ditylenchus sp.	Not common, found near stem	0 - 3"
Annelida	Earthworms	Few	0 - 6"
Mollusca	Slugs: Milax spp. / Cepaea sp. / Snails: Helicella sp.	Few / Small	Top soil
Acarina	Spiders / Mites: Tyrophagus (?) sp. / Pyemotes sp.	Few, small / Numerous, esp.red and brown ones	0 - 6"
Crustacea	Woodlice: Armadillidium vulgare Latr. / Oniscus asellus Linné	Few	In leaf litter
Myriapoda	Millipedes: Blaniulus guttulatus Bosc. / Polydesmus angustus Latz. / Centipedes: Geophilus sp. / Lithobius sp. / Haplophilus subterraneus Shaw.	Fairly common / Quite common	0 - 6" / Occ. on leaves

Class or order	Name	Remarks	Depth

Collembola	Springtails
	Smynthurus viridis (L.)
	  and others
		Numerous and
		  various
			0 - 6"

Dermaptera	Earwigs Forficula auricularia L.		In soil; on leaves and seed pods
Mecoptera	Scorpion fly Panorpa communis L.	Larva One only	0 - 3"
Lepidoptera	Cutworm larvae Agrotis segetum (Schiff.) Triphaena pronuba (L.) Ceramica pisi (L.) Pupa	Various Not very common ?	0 - 6" 0 - 3"
Coleoptera	Clay-coloured weevil O. singularis (L.)	Eggs, larvae Adult Pupae Diff. to extract	0 - 6" 0 - 6" 3 - 6"
	Vine weevil O. sulcatus (F.)	Not common Adults	0 - 6"
	Wireworm Agriotes obscurus (L.) Athous haemorrhoidalis (Fab.)	Numerous larvae One adult Numerous larvae	0 - 6" 0 - 6"
	Ground beetles: Carabus violaceous L. Stomis pumicatus (Panz.) Abax parallelopipedus (Pill. & Mitt.) Harpalus rufipes (Deg.) Feronia madida (Fab.) Bembidion quadrimaculatum (L.)	Larvae and adults	0-6"
	Rove beetles: Tachinis humeralis Graven. and others	Occasional	0 - 9"
	Small scarabid (?)	Larva	0 - 6"
	Cockchafer Melolontha melolontha (L.)	Larvae, rare	0 - 6" (5")
	Pselaphid beetles Claviger sp.	Adults	6 - 9"

Class or order	Name	Remarks	Depth
Hymenoptera	Ants: Lasius niger (L.)	Adults numerous	
	Bumble bees: Bombus spp.	Frequent in tunnels in soil	0 - 3"
Diptera	Leatherjackets: Tipula oleracea L. T. paludosa Meig.	Numerous	0 - 6"
	St. Mark's Fly: Bibio marci (L.)	Larvae occasional	0 - 6"
	Other dip. larvae (?)	Numerous	0 - 6"

TABLE (ii).   INSECTS AND OTHER SMALL ANIMALS FOUND AT WILLOUGHBRIDGE

AND KEELE ON RHODODENDRON BUSHES, 1962

Class or order	Name	Where found
Myriapoda	Lithobius sp.	Some on leaves at night in August
Dermaptera	Forficula auricularia L.	On leaves and seed heads
Lepidoptera	See list under "Lepidopterous pests"	
Coleoptera	Adalia bipunctata(L.) Coccinella septempunctata L.	On leaves
	Otiorhynchus singularis(L.) O. sulcatus(F.)	On leaves at night
	Agriotes lineatus(L.)	Few on leaves during day
	Phyllobius pomaceus Gyll.	On rhododendron leaves, but also on nettles
	Melolontha melolontha(L.)	Adults on flowers eating corolla
	Serica brunnea(L.)	On leaves at night
	Strophosomus melano-grammus(Forst.)	On leaves
Hymenoptera	Sawfly larvae (?)	On leaves

TABLE (III). INSECT PESTS FOUND ON RHODODENDRON SPECIES AT WISLEY, SURREY, FEBRUARY AND MAY 1962

English name	Genus and species	Rhododendron found	Date and Stage found
Rhod. White Fly	Dialeurodes chittendeni Laing.	On "Red Riding Hood" variety	February: Larvae on back of leaves May: larvae and pupae
Azalea White Fly	Aleurodes azaleae Baker and Moles	On R. mucronatum	February: larvae May: larvae and pupae
Rhod. Bug	Stephanitis rhododendri Horv.	On variety "Diane"	February and May: eggs in leaf along midrib
Rhod. Leaf Hopper	Graphocephala coccinea (Forst.)	Particularly on R. ponticum	February: eggs on bud scales May: eggs and some nymphs

The fungus disease Bud Blast (Sporocybe azaleae) was also found on many varieties.

Evidence of damage caused by:

Vine Weevil	Otiorhynchus sulcatus (F.)
Clay-coloured Weevil	O. singularis (L.)
Tortrix moth larvae	T. spp.

was also present on leaves.

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RHODODENDRON PESTS OF THE WORLD

In 1938 G. Fox-Wilson presented a paper to the VII International Congress of Entomology at Berlin entitled "Insect Pests of the Genus Rhododendron" and this was printed in 1939. Besides briefly describing some of the then known and more important rhododendron pests, the author lists arthropods found on Rhododendrons all over the world, along with their hosts, country of origin, and reference to the literature where they had been mentioned.

Many of the mites and insects are still found on the rhododendron, but others and also nematode pests have been noted since. The following pages will help to bring Fox-Wilson's list up to date.

TABLE (iv).   ANIMALS RECORDED, ON OR AROUND RHODODENDRONS,

WHICH ARE NOT MENTIONED IN FOX WILSON'S LIST 1939

Species	Host plant	Country	Reference
Tarsonemus palidus Banks			Pirone, Dodge and Rickett (1960)
Cyclamen mite	Azalea	U.S.A.	Morishita & Jefferson (1957).
Tetranychus bimaculatus Harvey Two-spotted spider mite	Azalea	U.S.A.	Pirone, D. & R.(1960) Davis and Libby(1961)
Paratetranychus ilicis McG. Southern Red mite		U.S.A.	Pirone, D.& R. (1960)
Brevipalpus inornatus Banks False spider mite or Privet mite		U.S.A.	Pirone, D. & R.(1960)
Thrips tabaci Lindeman Thrip	Seedlings of rhododendron and azalea	U.S.A.	Pirone, D. & R.(1960)
Aculus rhododendronis Keifer Azalea rust mite	Azalea	U.S.A.	Keiffer (1959)
Pseudococcus cuspidatae	Rhododendron	U.S.A.	Rau, J. (1937)
Tetraleurodes mori Quaint Mulberry white fly	?	U.S.A.	Kerr (1959) Weigel and Baumhofer (1948)
Aspidiotus pseudospinosus Rhododendron scale	Rhododendron	U.S.A.	Davis and Libby(1961)
Nematodes:			
Tylenrhorhynchus spp.	Rhododendron	U.S.A.	Davis and Libby (1961)
Tylenrhorhynchus claytoni	Azalea	U.S.A.	Sher (1958)
Trichodorus Christiei	Rhododendron	U.S.A.	Rohde and Jenkins (1957)

Species	Host plant	Country	Reference
Tylenchus sp.	Rhododendron	U.S.A.	Pirone, D. & R. (1960)
Ditylenchus sp.	Rhododendron	U.S.A.	Pirone, D. & R. (1960)
Rotylenchus robustus	Rhododendron	U.S.A.	Tarjan (1953)
Xiphenima americanum	Rhododendron	U.S.A.	Christie (1952)
Meloidogyne incognita	Rhododendron	U.S.A.	Hunt (1957)
Giardomyia rhododendri Felt Rhod. gall midge	Rhododendron	U.S.A.	Felt (1939) Pirone, D. & R. (1960)C.W.
Pantomorus godmani Crotch Fullers Rose Beetle	Rhododendron	U.S.A.	Weigel & Baumhofer (1948)
Serica brunnea(L.) Chafer	Rhododendron	G.B.	Schofield
Phyllobius pomaceus Gyll.	Rhododendron	G.B.	Schofield
Arthrochlamys spilota	Rhododendron	Japan	Kumazaw (1939)
Vespa crabro germana Christ.	Rhododendron	U.S.A.	Pirone, D. & R. (1960)
Setones waterhousei	Rhododendron	G.B.	Millais (1924)
Scoliopteryx Libatrix(L.) Herald moth	Rhododendron	G.B.	Schofield
Agrotis segetum(Schiff) Common Dart	Rhododendron	G.B.	Schofield
Bena prasinana(L.) Green Silver lines	Rhododendron	G.B.	Schofield
Hepialus humuli(L.) Ghost Moth	Rhododendron	G.B.	Schofield
Adela resumurella(L.) Green longhorn moth	Rhododendron	G.B.	Schofield
Agrochola macilenta(Hueb.)	Rhododendron	G.B.	Schofield

Species	Host plant	Country	Reference
<u>Trichopterux polycommata</u>(Schiff.) Barred tooth-striped	Rhododendron	G.B.	Schofield
<u>Erannis progemmaria</u>(Huebner) Dotted border	Rhododendron	G.B.	Schofield
<u>Melanchra persicariae</u>(L.) Dot moth	Rhododendron	G.B.	Schofield
<u>Plusia chrysitis</u>(L.) Burnished Brass	Rhododendron	G.B.	Schofield
<u>Pandemis cinnamomeana</u>(Treit.)	Rhododendron	G.B.	Schofield

THE PESTS OF RHODODENDRONS IN GREAT BRITAIN

IN THE ORDERS:

a. Hemiptera
   - i. Rhododendron Whitefly
     (Dialeurodes chittendeni)
   - ii. Rhododendron Bug
     (Stephanitis rhododendri)
   - iii. Rhododendron Leaf-hopper
     (Graphocephala coccinea)
   - iv. Azalea Whitefly
     (Aleurodes azaleae)
   - v. Aphis

b. Lepidoptera
   Moth caterpillars
   Azalea Leaf-miner
   (Gracilaria azaleella)

c. Coleoptera
   - i. Clay-coloured weevil
     (Otiorhynchus singularis)
   - ii. Vine weevil
     (O. sulcatus)
   - iii. Cockchafer beetle
     (Melolontha melolontha)
   - iv. Sandy chafer
     (Serica brunnea)
   - v. Nut leaf weevil
     (Strophosomus melanogrammus)
   - also (Phyllobius pomaceus)

d. Hymenoptera
   Leaf-cutter bee
   (Megachile sp.)
   Sawfly (unknown)

e. Nematoda
   Xiphenima sp.
   Ditylenchus sp.

f. Mollusca
   Slugs

RHODODENDRON WHITEFLY (DIALEURODES CHITTENDENI LAING)

THE HISTORY AND CONTROL IN GREAT BRITAIN

First noted by Hoare, 1926, who found pupal cases on rhododendrons at Chiddingford, Surrey, and sent them to be identified by Laing at the British Museum. Hoare's report was published in 1928 and he doubtfully regarded the pest as *Pealius sp.*

In the same year, Mr. Fred J. Chittenden, Director of the Wisley Gardens, writing in the Gardeners' Chronicle (Chittenden 1928) and in the Fruit Grower, drew the attention of rhododendron growers to a new pest which had recently appeared in Berkshire gardens and which bore a great resemblance to the well known whitefly of greenhouses. His claim that it was a new species was challenged in the correspondence columns. A writer in the Fruit Grower suggested that the whitefly found in Surrey by Hoare and that found by Chittenden in Berkshire were the same species and that the two occurrences were related, also that each species of whitefly had its own distinct host.

In October 1928, Laing cleared up the situation in an article in the "Entomologists Monthly Magazine". He says: "I have known of this insect since 1926, when I received a few pupa cases through the Ministry of Agriculture, but it is not until this summer that material satisfactory for descriptive purposes came to hand. It is named after Mr. Chittenden as a token of esteem". Laing describes the pupal case and adult, and writes: "Though the species is not typically a *Dialeurodes*, it may conveniently rest in that genus until the classification of the

family is better understood".

Trials were carried out to control the pest by spraying
(Fox-Wilson 1929), and in 1935 Wilson gave a brief description;   this
article was revised and reprinted in 1948.   The control was then said
to be (as it had been in 1935 also):-

Summer white oil, 1¾ pints; Nicotine, 96%, ¾ fl. oz;   Water, 10 gallons.

The pressure should be at least 90 lb. per square inch and
sprayed in September in dull weather.

Latta (1936) wrote of the latest experiments with 2% oil sprays to
control Rhododendron Whitefly after heavy infestations of the pest
had been discovered in Washington State in 1933.   He listed the different
varieties infected in the U.S.A. and noted that the susceptibility
appeared to depend on physical differences in the leaf surface.

Deshpande, writing on British Aleurodidae (1933), gave a short
description and measurements of egg, larvae and adult of D.chittendeni.

In his studies on the British Whiteflies, Trehan (1937), described
the egg, nymphal stages and adults.

More recently, this pest has spread to other parts of Europe (Saalas
1942), having been noted in Finland, Sweden, Germany and Holland, and is
fairly common in the U.S.A.

Kerr (1953) compared and published the results of trials with
different insecticides on Rhododendron Whitefly.   He found that 75% DDT,
25% lindane and a 40% solution of nicotine sulphate were all effective
for controlling the insect, and that the DDT was slightly more effective

than the other two, especially at the lower concentration of 0.67 lb.
per 100 gallons of water applied twice.   The DDT and lindane effectively
prevent oviposition, and most of the young hatching from the few
remaining eggs were killed by the residual deposits on the leaves.
Nicotine sulphate was effective mostly as an ovicide.

Low volume spraying with DDT or BHC applied by aerosol, or
DDT emulsion applied at the end of June give effective control until
autumn (Hasse 1957).

Pirone, Dodge and Rickett (1960) suggest spraying with lindane
or malathion, directing the spray to the underside of leaves and the
terminal clusters.   Malathion is also recommended by Bowers (1960),
and Kerr (1959) mentions malathion as a control against the adults, but
says it is not so effective against the newly hatched larvae.

Because the use of DDT is no longer recommended, malathion
should be used as an effective control in Great Britain.   There are
no known natural enemies of D. chittendeni.

SYMPTOMS OF ATTACK

These are:-

a. Yellowish mottling of the upper surface of the distal leaves
   of the plant.

b. The presence of sooty moulds and honeydew on the top surfaces
   of leaves (Plate 4).

c. Small, oval larvae and pupae or white pupal cases on the
   undersurface (Plate 3).
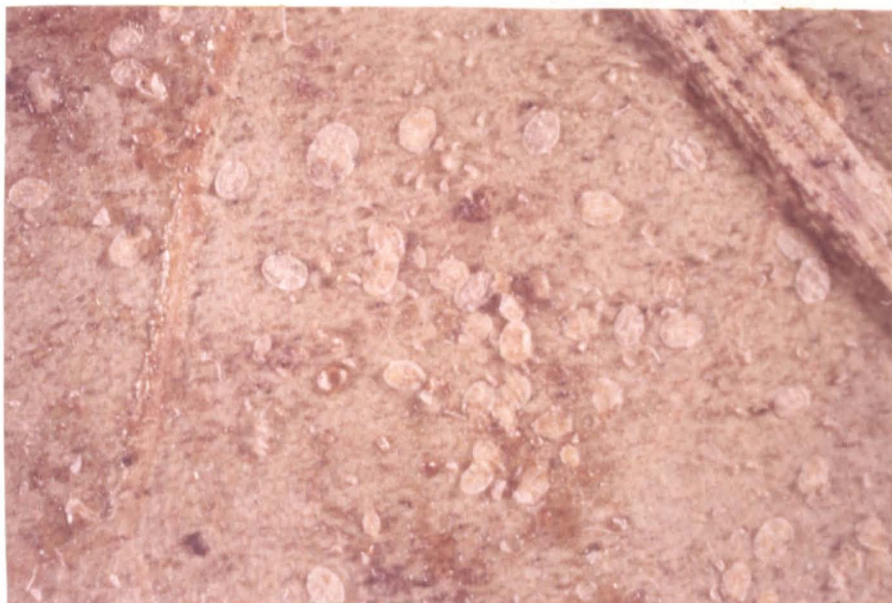
Plate 3.

a. x 11
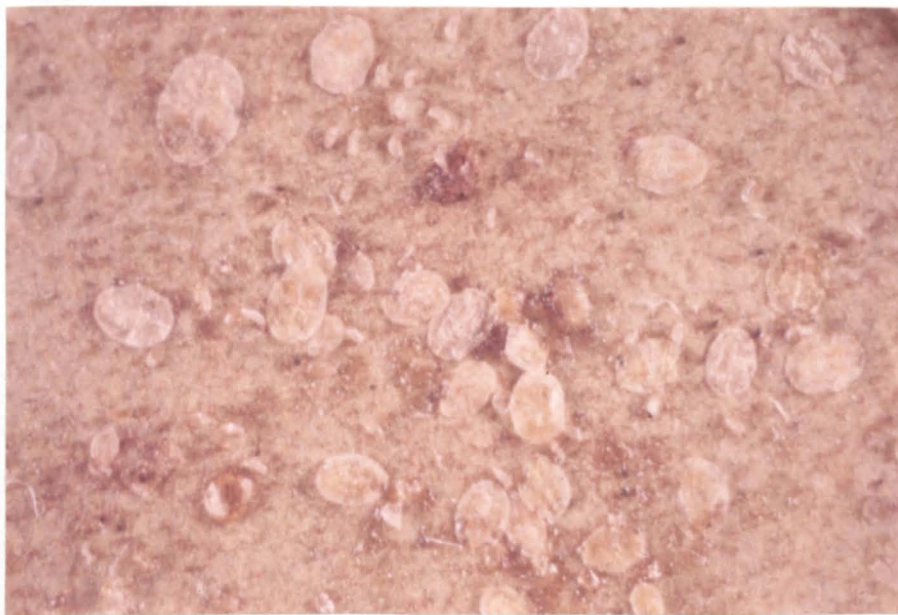
b. x 20.

<u>Rhododendron Whitefly eggs and nymphs on underside</u>
<u>of leaf.</u>

Plate 4.

Sooty mould, (Capnodiaceae), on upper
surface of rhododendron leaf.

d. Presence of the yellowish-white adults clustered under the leaves, especially apparent when the branch is shaken and they fly.

e. In heavy infestations, the margin of the leaf may roll inwards.

TYPE OF PLANT ATTACKED BY RHODODENDRON WHITEFLY

The insect favours the host plant with a smooth rather than a glaucous leaf (Chittenden 1928). All the varieties from which I have collected D.Chittendeni have been of the smooth-leaved type.

The following have listed the different species and varieties of Rhododendron on which D. chittendeni has been found: Latta (1937), Fox-Wilson (1938), Kerr (1953).

I have found the fly also on the variety "Red Riding Hood" in Surrey in 1962, 1963.

Adult white flies have been found at rest on the leaves of rhododendrons which have non-smooth leaf surfaces and also on other plants such as Kalmia, Pieris and Gaultheria growing near to the rhododendron plants, but there is no evidence to show that the Rhododendron Whitefly has ever bred on any of these plants. No instance of feeding or oviposition or of the presence of larvae or pupae on other than smooth-leaved rhododendron plants has been observed by me or any of the writers.

DESCRIPTION OF THE STAGES IN THE LIFE CYCLE
OF DIALEURODES CHITTENDENI

All these stages have been described by Trehan (1937), pupa and adult by Laing (1928).

LIFE HISTORY OF D. CHITTENDENI ON OUTDOOR

RHODODENDRONS IN GREAT BRITAIN

This has been described by Fox Wilson (1948) and is confirmed by my own observations.

Eggs are laid on the underside of smooth-leaved varieties from mid-June until early August.   They are laid singly on a long peduncle.

Elliptical nymphs hatch after eight to fifteen days and are most noticeable on the infected plants from July until the following April or May.   They are greenish-yellow, the same colour as the underside of the leaf.

Nymphs are active and walk about on the leaf after hatching, then become sedentary and feed by inserting the stylet into the leaf tissues.   The legs gradually become degenerate.   There are three instars, during which the insect sucks plant sap and the damaged leaves appear mottled on the upper surface.   Following the yellow mottling, sooty moulds grow on the surface of the leaves, feeding on the honeydew excreted by the larvae.   This honeydew falls on to leaves below those on which they are feeding.   The black moulds are not directly parasitic on the leaves, but cause unsightliness and impair the normal functions of a leaf (Plate 4).

The greenish and almost transparent nymphs are difficult to see, as are also the flat, broad, elliptical pupae which are found normally in May, but also during the summer months.

Adults are light yellow with white, mealy wings and are found swarming in clusters during June and July, normally on the underside of the topmost leaves of the rhododendron plant. When distributed they will fly upwards, but generally remain settled on the leaves, especially during dull, cold or cloudy weather. Both male and female whiteflies, which are similar in shape and colour, are found together in fairly equal numbers, although there may be a slightly higher number of females.

(The terminology used in the description of this pest is open to some comment. Most of the insects in this group, the homopterous Hemiptera, have the stages egg, nymph and adult in their metamorphosis. Some of them, including Dialeurodes chittendeni, exhibit a stationary "nymphal" stage after the third instar. Because this is so different from the normally acttive last nymphal stage, it is referred to as a pupa, being more like the inactive pupal stage in other insects whose metamorphoses show the egg, larval, pupal and imaginal stages.

Hinton (1962) states that in some exopterygotes, e.g. Aleyrodidae, there are feeding larval instars followed by a quiescent larval instar.

"No difficulty necessarily arises if these quiescent or semi-quiescent stages of exopterygotes are called pupae provided that it is recognised that their origin is quite independent from that of the endopterygote pupa and their initial functional significance is different".)

There is only one generation per year, but many stages can sometimes be found in the same month because of the dependence on the
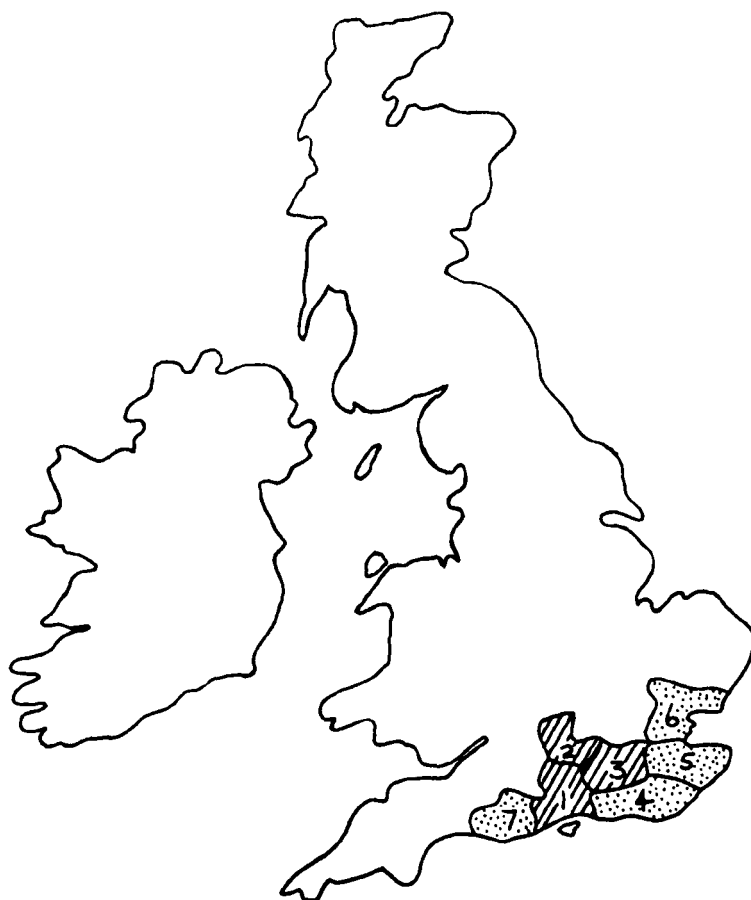
Distribution of _Dialeurodes_ _chittendeni_

in the counties of the British Isles.

▨ ▨ ▨ Present as pest.

▨ ▨ ▨ Found only on a rare occasion.

1. Hampshire   4. Sussex

2. Berkshire   5. Kent

3. Surrey   6. Essex

7. Dorset.

Fig 1.

weather, temperature and climatic conditions for each stage in the life
cycle to be completed. No two years' timings seem to be the same.
Low temperature and dull weather retard the stages of the life cycle.

In Staffordshire, the introduced whitefly died out and did not
develop. Small-leaved varieties of Rhododendron had been introduced
from the South of England and were found to have whitefly nymphs on the
backs of the leaves. The plants were at first grown apart from the main
garden and were examined frequently. Once the nymphs had ceased to
develop further, the shrubs were incorporated into the main rhododendron
garden.

STATUS OF D. CHITTENDENI AS A PEST OF RHODODENDRONS IN GREAT BRITAIN.

Because of present chemical sprays, Rhododendron Whitefly is no
longer the pest in Britain that Chittenden gloomily forecast in 1928.

It is seen only occasionally on a few varieties of rhododendron,
and then only in the south of England. Cox and Cox (1956) do not record
it from their large nursery in the West of Scotland, but it has been found
on commercial nurseries in the home counties. I have seen no trace of it
in the Midlands or in Lancashire, or in North Wales.

RHODODENDRON BUG

STEPHANITIS RHODODENDRI, HORVATH (SYN. LEPTOBYRSA RHODODENDRI, HORVATH)

This hemipterous insect is known in Great Britain as the Rhododendron Bug, and in the U.S.A. as the Rhododendron Lacebug.

HISTORY

First observed in Great Britain in 1901 by Raffill (1933) at Kingston-on-Thames, on plants imported from Holland, and then by Harding in 1906 (Harding 1930).   (This is contrary to the M.A.F.F. Ad. leaflet No. 206).   In 1910 Distant wrote about the pest, and it was further described by Theobold in 1912 and 1914.

The earliest records are from the U.S.A. in 1877 (Heidemann 1909) where it is thought to be an indigenous pest, and was probably introduced to Great Britain from America via Holland.   In about 1905 there were reports of Rhododendron Bug in Holland, Belgium, France, Germany and Austria and, more recently, in Japan.

Distant (1910) thought it to have come from India, but this species was not found to be indigenous to India and this theory is now discredited.

Horvath described the insect in 1905, naming it Stephanitis, and in 1908 Heidemann renamed it Leptobyrsa.   Johnston (1936) states it should more correctly be in Leptobyrsa, but at present the name Stephanitis is commonly used (Kloet and Hincks 1964).

SYMPTOMS OF ATTACK

The upper surfaces of the leaves appear spickled, covered with many tiny, yellow dots as shown (Plate 5a).

Plate 5.
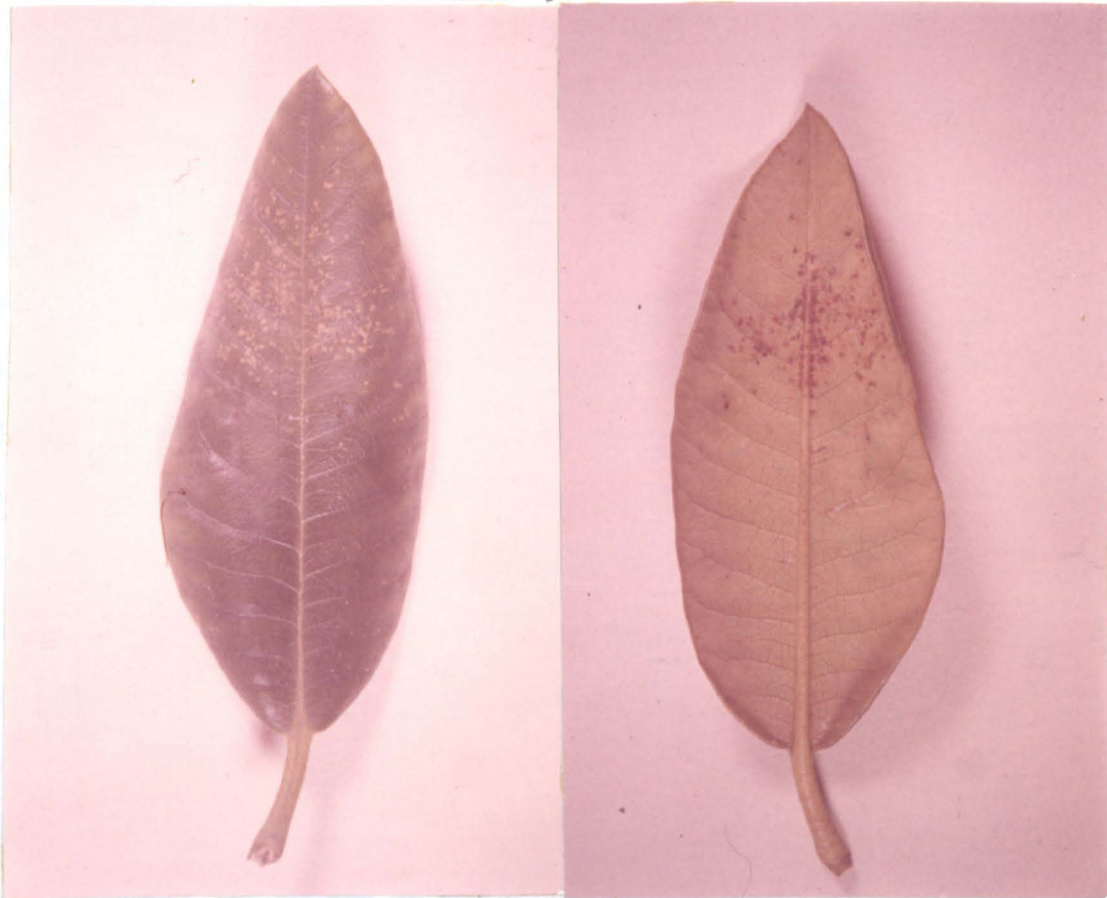
a. and b. Upper and lower surface of leaf.

x $\frac{3}{4}$

Symptoms of Rhododendron Bug attack.

c. Brown, stickiness along lower midrib of leaf
Open necks of egg chambers can be clearly seen.

x 12

Chocolate-brown markings are seen on the lower surfaces of the leaves, especially noticeable bordering the midrib. Brown sticky secretions are exuded and a general scruffy, rusty appearance is typical of attack by this bug (Plate 5b).
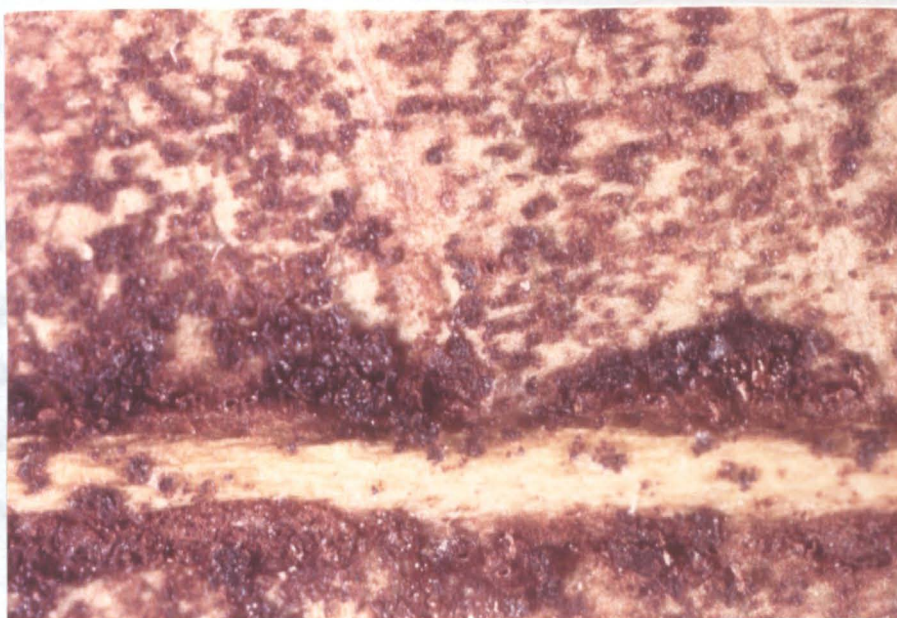
Millais (1924), Slocock (1934), Johnson (1937), Fox Wilson (1939) and the M.A.F.F. Advisory Leaflet 206 (1953) all list species and varieties of Rhododendron which are immune or susceptible to attack.

I have only seen the bug on the following varieties:-
"Diane" and "Blue Ensign" at Wisley, Surrey; R. campylocarpum and hybrids and "Ascot Brilliant" at Slococks, Surrey, and Anglesey at Plas Newydd, var: "Old Port" (imported plants).

Because so few bushes are attacked in Great Britain, it has been difficult to discover the causes of susceptibility or immunity. It could be as much due to the positions of the particular bushes, i.e. whether in light or shade, as to the species concerned. It was suggested by Millais and in the Bulletin of the Arnold Arboretum (1931) that plants suffer more from rhododendron bug in sunny positions, particularly if exposed to drying winds, than if in cool shade. Bushes in shaded woodlands are not much attacked.

LIFE HISTORY AND DESCRIPTION OF S. RHODODENDRI

Described in detail by Johnson (1936, 1937).

Entomologically it is an interesting insect, each stage being quite distinctive and unlike any other pest to be found on ornamental plants in Great Britain.

Plate 6.

Rhododendron Bug.

Enlarged photograph (x 7) of midrib on lower
surface of rhododendron leaf, showing the
opening or cap above the egg, also shed skin
of nymph.

egg caps

midrib

nymphal
skin.
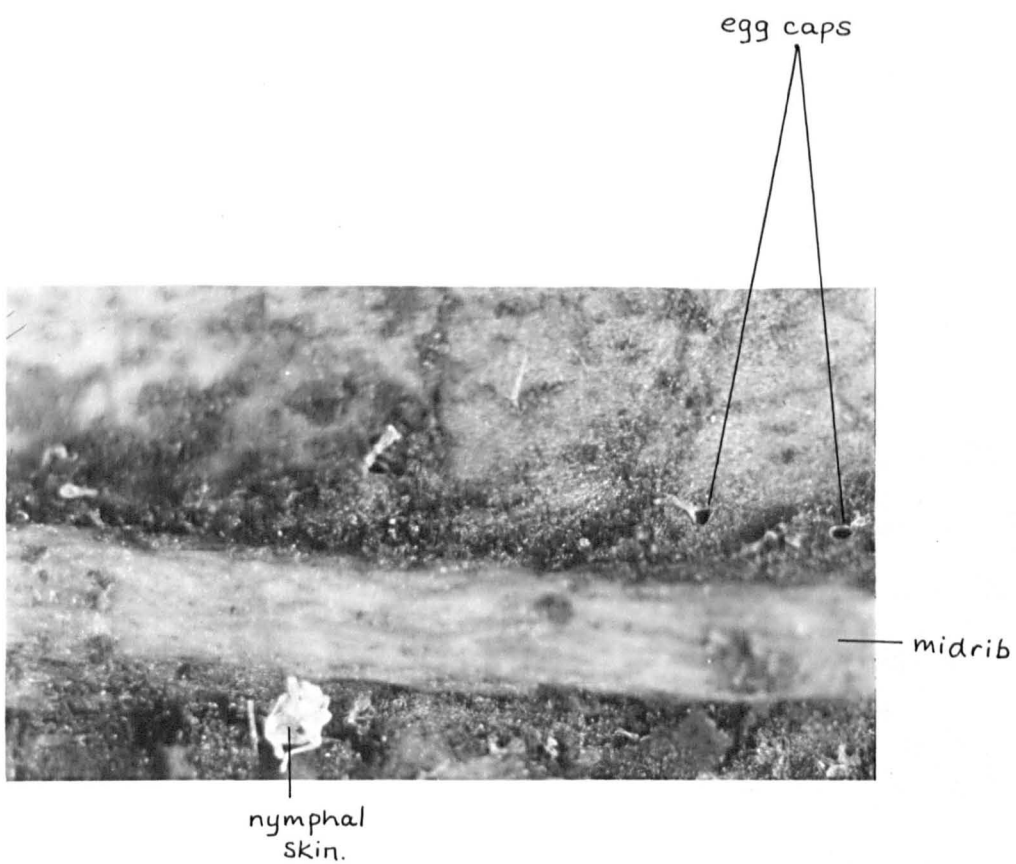
<u>Adult</u>:   July-October.   Found on leaves of previous year.

About 3 mm. long.   The black body is covered by relatively large, lacey wings, from the front of which project a pair of lace-like rounded outgrowths.

The wings are hardly, if ever, used.   The bugs may be blown on to adjacent bushes, or walk across where branches touch.   Transference of rhododendron bug is more likely to be by moving of imported plants infected with insects or their eggs.

There are male and female of the species.   Mating begins mid-July.

<u>Egg</u>:   July-autumn.

0.5 mm. long, flask-shaped, almost cylindrical and slightly curved.

The cap of the egg is flush with the leaf or gall epidermis and is black with a white collar.   Many eggs are embedded in the brown lumpy leaf galls along the sides of the midrib (Plate 5c).   Some eggs are laid singly in the leaf where no galls form.

Over the cap the adult places a drop of olive-green, faecal fluid which dries to form a brown crust or scab on the cap.

Eggs hatch within a few hours of each other, usually in the first two weeks of June in Great Britain, the nymph lifting the cap.   A detailed description of this action is given by Johnson.   The egg-sac remains within the leaf while the cap and embryonic membrane hang out of the open neck (see Plate 6).

<u>Nymphs</u>:   May-June.

After emerging they cluster together on leaf.   They are pale green or colourless at first, spiny and hairy, about 0.9 mm. long,
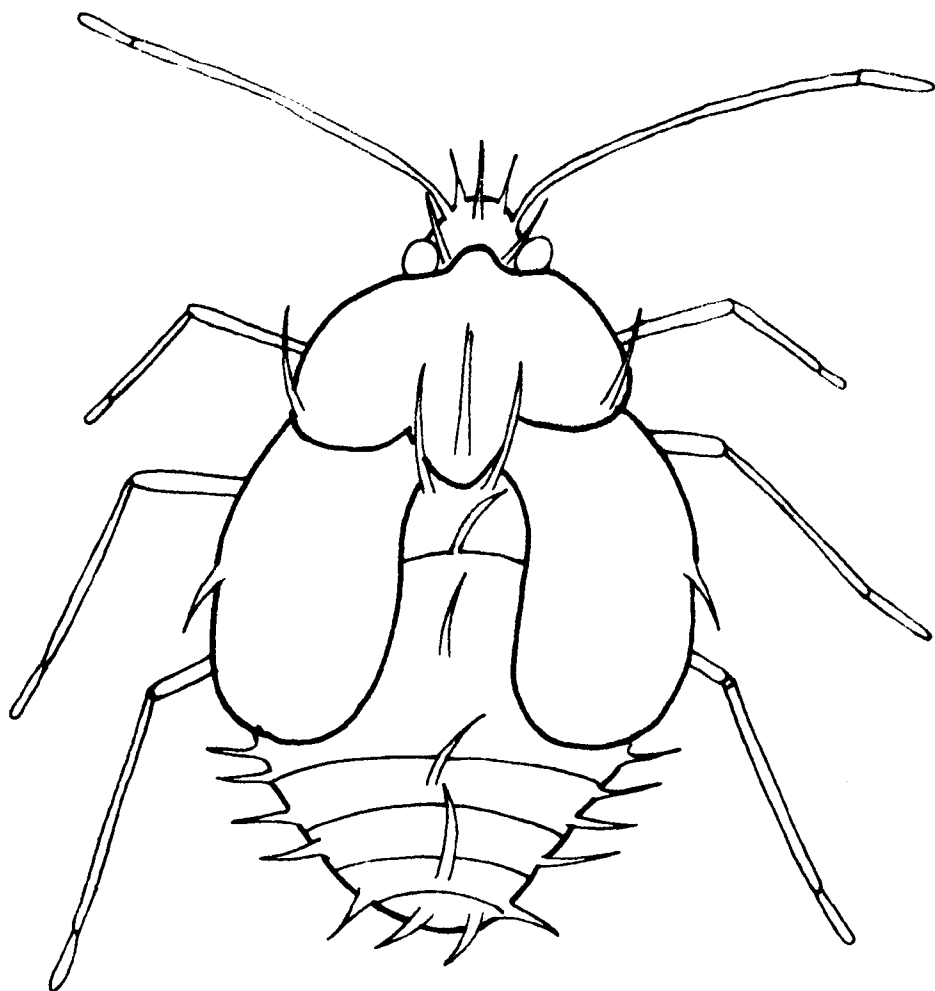
Nymph of S. rhododendri.   2mm long.

Fig. 2a

Stephanitis rhododendri
3·5 mm.

Fig. 2 b

growing to 2 mm. and becoming yellowish-brown by the fourth instar.
(Fig. 2a).

CONTROL OF RHODODENDRON BUG

A.   Take off infected leaves and burn, even prune the plant back.
     Spray several times on the underside of leaves at the time of
     year when the nymphs and adults are on them.

B.   The following chemicals have been recommended:-

     Pyrethrum extract (Borton 1942), mid-June, sprayed with atomizer
     (Sy, M. 1936.) Quassia and soft soap (Harding, 1930).   Derris
     at commercial strength + 0.5% soap; spray on several applications
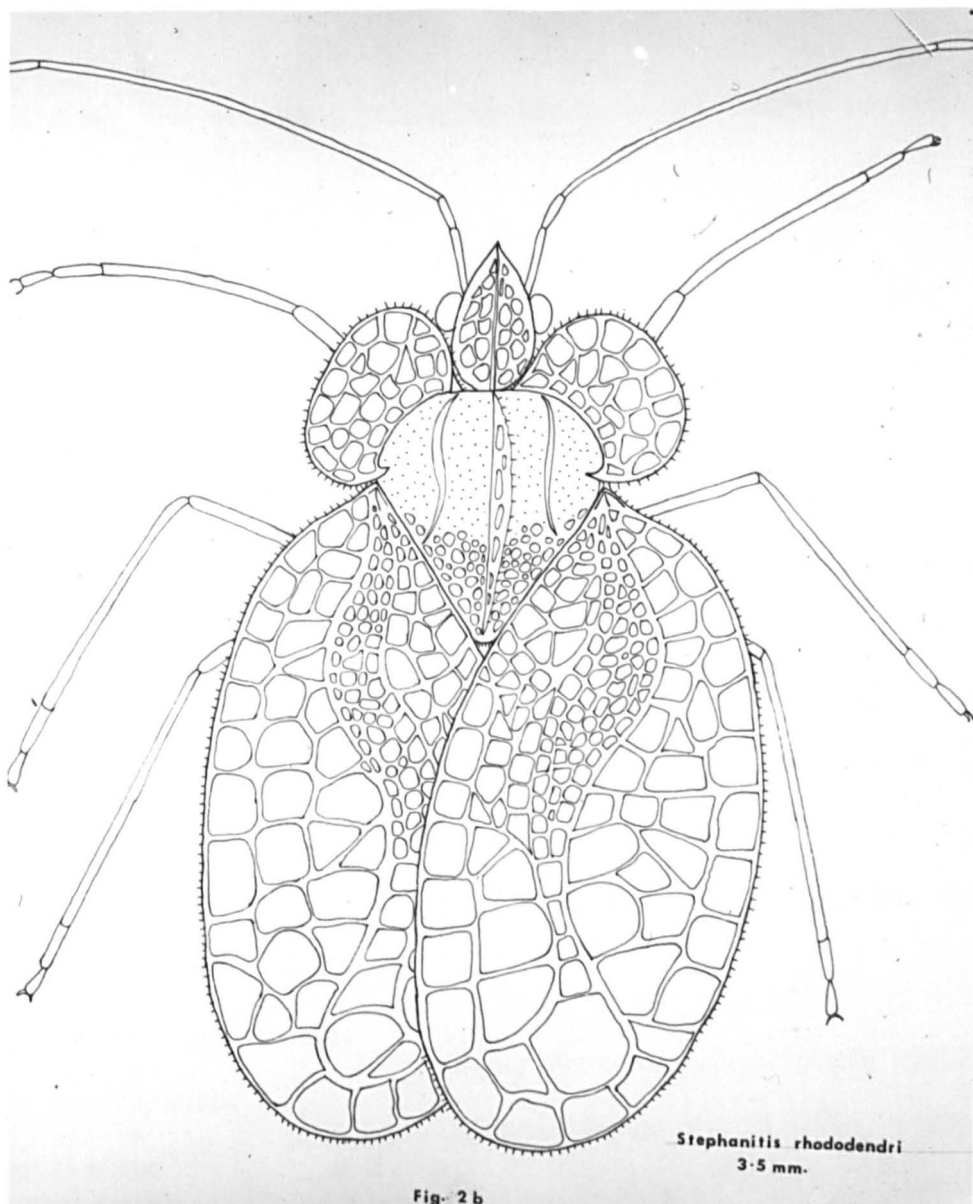   (Sy, M. 1936).   Nicotine solution + 2% soap solution (Sy, M. 1936).
     8 fl. oz. per 100 gall. nicotine solution + spreader (M.A.F.F.
     Advis. leaflet 206).   Dimethoate granules to soil (Schread 1960),
     (Can poison cats and dogs).

     DDT 50% wettable powder)
               +   )   Early June in U.S.A. (Kerr 1954)
     50% Methoxychlor   )
               +   )   (Pirone, Dodge and Rickett, 1960)
     25% lindane   )

     Thimet (for azalea lace bug) - 8% granules raked into soil, soaked
     (Schread 1959).   Malathion sprayed under leaves (Pirone, Dodge and
     Rickett, 1960).   TEPP at 4 fl. oz. per gall. plus wetter (M.A.F.F.
     Advis. leaflet 206).   HETP at 8 fl. oz. per 100 gall.   Two
     applications mid-June and early July (M.A.F.F. Advis. leaflet 206).

PRESENT STATUS AS A PEST IN GREAT BRITAIN

     The Rhododendron Bug is now controlled by organophosphorus

Distribution of _Stephanitis_ _rhododendri_

in the counties of the British Isles.

[///] Present as pest.

[:::] Found only on rare occasions.

1. Hampshire   4. Part of Yorkshire

2. Berkshire   5. Durham

3. Surrey   6. E. Lowlands of Scotland

Fig 3.

insecticides and is only rarely seen on rhododendrons in Great Britain.
(Never has it built up to serious proportions, but it is a pest which
should be recognisable by the grower of rhododendrons in case it should
be imported from North America or Europe and need to be controlled).

According to the N.A.A.S. regional entomologists, it has only
been found in Hampshire, Surrey and Berkshire in recent years, and on
very rare occasions has been seen in the Edinburgh district and mid-
Yorkshire.   Johnstone (1936) records it from southern counties before
1936 and states: "The physical factors which may limit the distribution
of the bug in Great Britain are probably mainly those which limit the
distribution of susceptible varieties and species of Rhododendron".
But Fox Wilson (1939) says that the factors are not known because
susceptible varieties and species of Rhododendron are grown in the West
coast of Scotland and in Ireland where no records had then, and still
have not, shown this pest.

RHODODENDRON LEAF-HOPPER, (GRAPHOCEPHALA COCCINEA (FORSTER))

THE HISTORY AND CONTROL IN GREAT BRITAIN

This species had been known and named in the United States and
Canada before it appeared in a garden in Chobham, Surrey, and was
collected by Barton in 1933.   W.E. China of the British Museum (Natural
History) identified the insect.

Many more outbreaks occurred in Surrey in 1936 and Wilson saw
adults on bushes at the end of September (Fox Wilson 1937).   He quotes
Waterer as saying that his men had seen it on the rhododendrons at
Windlesham Moor for at least four or five years and called it "Grasshopper
Fly".   It may be, therefore, that the original outbreak was at
Windlesham on imported plants.

The first control (Wilson) in Great Britain was nicotine dust.
He states that this was more effective than the spray, due to the
agility of the hoppers.   The spray fluid would not penetrate into dense
bushes.

Baillie and Jepson (1951) quote preliminary experiments at
Silwood Park by Walker: DDT spray (0.1 to 0.2%).   Spray during egg
laying period, i.e. 2 - 3 weeks after first adults seen (August 1st -
October 1st).   Treated leaves remained toxic for 2 - 3 weeks.

They suggest that isolated, susceptible bushes be sprayed each
fortnight from August 1st until October.   Contrary to Wilson, they
found that the adult Graphocephala coccinea feeds and rests mainly on
the upper surface of the leaves, and it is not necessary to spray inside

the bushes.

Baillie (1950) and Pirone, Dodge and Rickett (1960) state
that control of lace bug Stephanitis rhododendri Horv. will control
leaf-hopper, but as the former lives on the underside of leaves the
bush must be thoroughly sprayed.

To control both the leaf-hopper and bud blast disease, which
are often found on the same bush, a combined DDT and Bordeaux spray may
be given.

Should Graphocephala ever become a serious pest, resistant
varieties of rhododendrons may have to be grown.   According to preliminary
work done by Baillie and Jepson (1951), early varieties which shed their
bud scales before the attached eggs hatch and those varieties with very
loose scales (R. griersonianum), where no eggs have been found, may be
used directly or as parents for resistant varieties.

Modern American literature on rhododendron pests does not
mention this insect, so I conclude that although it has been endemic
there for at least half a century, it is no longer regarded as a serious
pest in the U.S.A.

SYMPTOMS OF ATTACK

First signs of attack are often the white, nymphal, shed
skins on the underside of the leaves (Plates 10 & 11).   The green nymphs
run over the under surface of the leaf and the colourful adults leap
about rapidly when disturbed, neither are easily caught.

Eggs lie flat on the bud scales, but these, being greenish-

Plate 7.

a. Eggs of the leaf-hopper, Graphocephala
       coccinea, laid on the scales of a
           rhododendron bud.   x 6.

b. Leaf-hopper eggs, well camoulflaged
        on rhododendron bud.   x 1.

yellow, are not easily seen by the grower (Plate 7).

The leaf-hopper pierces the leaf and extracts cell sap during both the nymph and adult stages, but it can be seen from the photographs that no apparent damage is caused.

Often bacteria will invade the punctures in the leaves, and brown spotting of the foliage then occurs as secondary damage around the feeding areas.

IMPORTANCE OF G. COCCINEA AS A PEST OF RHODODENDRONS

Although the insect causes little or no direct damage to the leaves despite its feeding by sucking cell sap, members of this family, Jassidae, often transmit diseases (Short, 1963). Also the saliva of some leaf-hoppers is known to cause leaf-burn on a wide range of plants.

It is not surprising, then, that when the disease known as Bud-blast of Rhododendrons was found on the same bushes as G. coccinea, this insect was suspected of transmitting the disease. The disease is caused by the fungus Sporocybe (Pycnosteanis) azaleae, coremia of which can be seen on the rhododendron buds after the bud has turned brown and died (Plate 8).

Work was carried out by Baillie and Jepson (1951) into the relationship between the insect and the fungus, and they claim "on the basis of work over two seasons to have shown a significant association of bud blast with Graphocephala coccinea".

Bud blast is a serious disease which, when established, can kill most of the buds on a rhododendron bush.

DISTRIBUTION OF RHODODENDRON LEAF-HOPPER IN GREAT BRITAIN

In 1935 it was found in Surrey, and the records of outbreaks

Plate 8.

Bud of rhododendron showing coremia
    of Sporocybe azalea causing
      Bud Blast disease.   x 8.
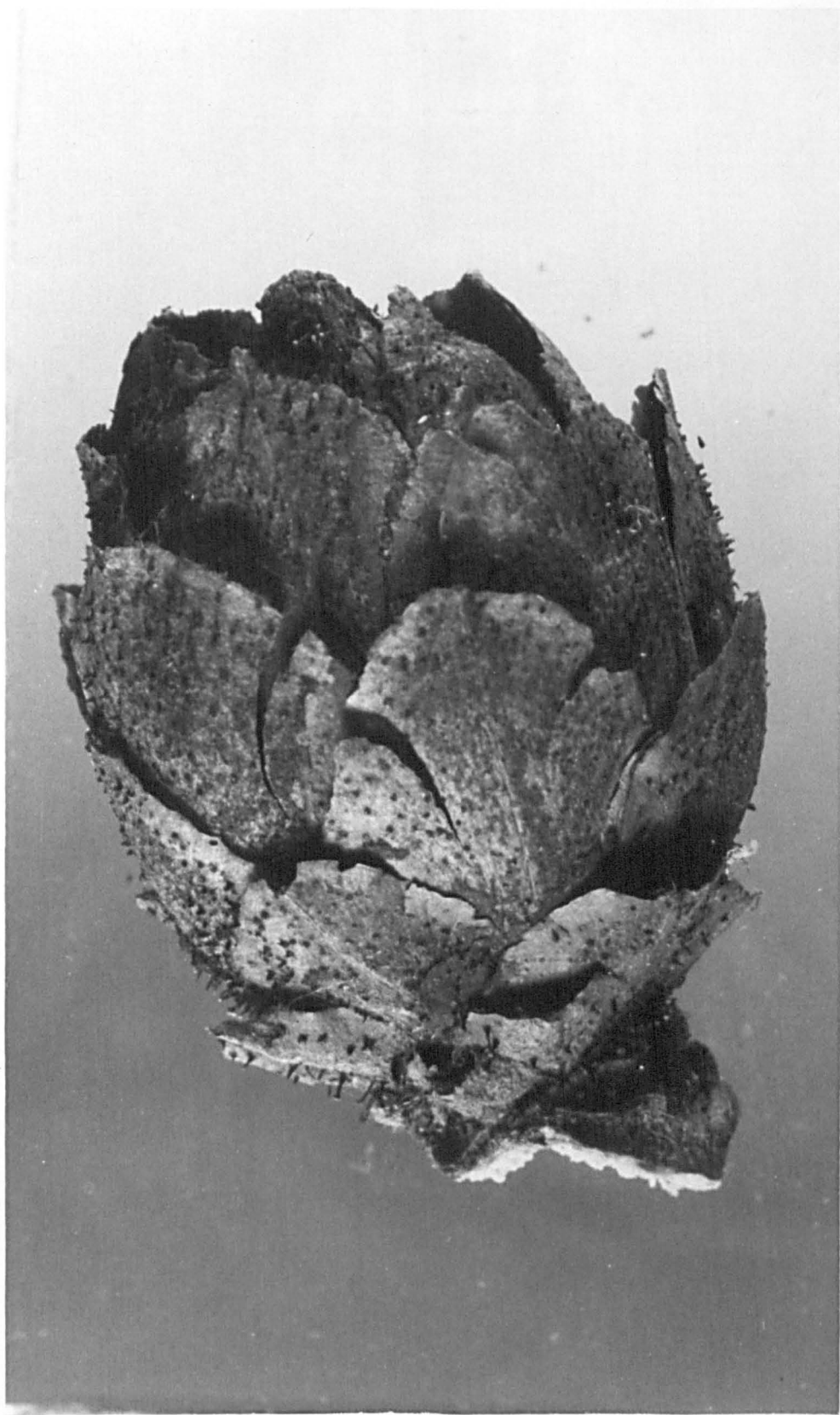
Distribution of _Graphocephala coccinea_

in the counties of the British Isles.

▨ Present as pest.

▨ Found only on a rare occasion.

▨ Bud blast disease only.

1. Hampshire   3. Surrey

2. Berkshire   4. N. Lincolnshire

        5. Buckinghamshire.

            6. Anglesey.

            Fig 4.

in the next year were also confined to that area:

Chobham (2); Windlesham (2); Woking (2).

The only other host appeared to be Kalmia (Wilson 1937).

From my own observations in 1963 and 1964, I have seen rhododendron leaf-hopper on R. ponticum in Surrey, and some adult leaf-hoppers were seen in Anglesey in 1970 on plants brought from Surrey. Rhododendrons examined in Staffordshire, Warwickshire, Shropshire, Lancashire, and more recently in Caernarvonshire have been free both of the insect and of Bud-blast disease.

Information collected from the N.A.A.S. regional entomologists show it to have been found in Surrey, with a probability that it is in Hampshire and Berkshire. There is a record of one case in Lincoln some years ago. All other N.A.A.S. regions report the absence of the pest. (I have a record of Bud-blast disease from Slough, Buckinghamshire in March 1962).

Baillie and Jepson (1951) report the absence of G. coccinea from the West of England, Somerset, Bodnant and Fort Augustus, Invernesshire.

It seems likely that this pest has not spread in Great Britain since its initial occurrence in Surrey in 1935.

DESCRIPTION OF THE STAGES IN THE LIFE CYCLE OF G. COCCINEA.

In order Hemiptera; Sub-order Homoptera; Family Jassidae.

Egg: Oval, elongate. Yellowish-green. About 4 mm. long.

Laid singly on scale or in groups of 5 - 10.

Nymph: Light green. 2 mm. on hatching. Four nymphal stages.

Plate 9.

a. x 6.

b. x 6.

Young nymph of rhododendron leaf-hopper after 1st
moult. Note cast skin and the brown, dead patches
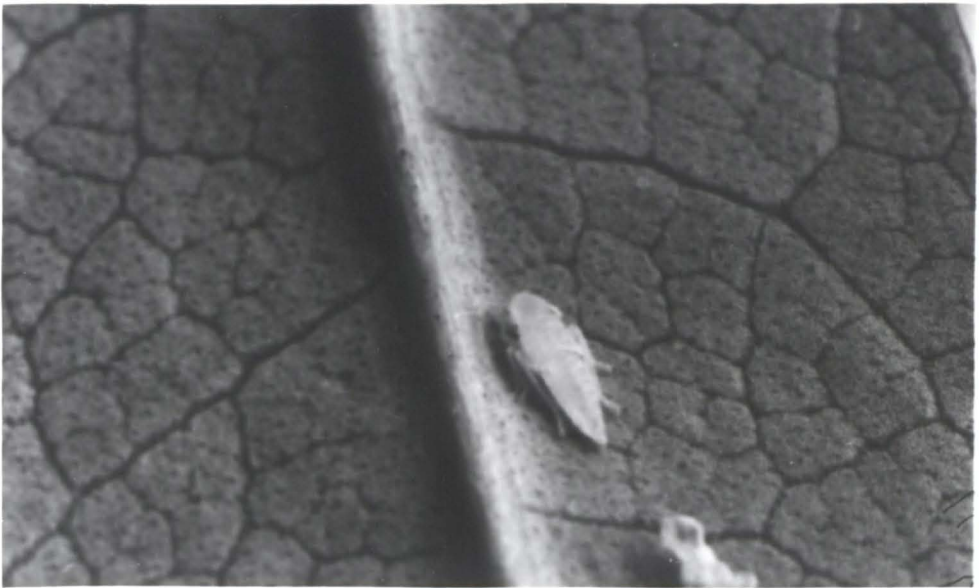probably around feeding areas.

Plate 10.

Cast skins of nymph of rhododendron
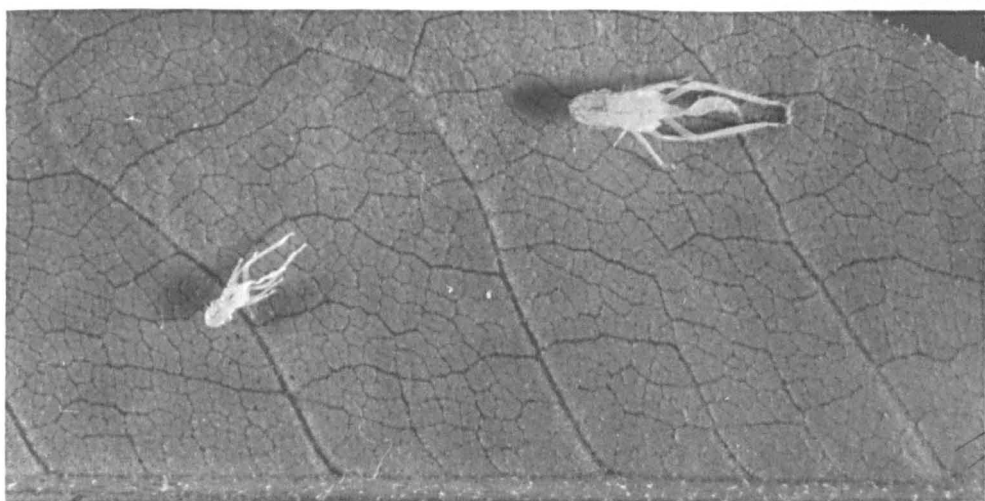leaf-hopper after 1st and 2nd moult. x 5.

Plate 11.

Cast skin of rhododendron leaf-hopper
after 3rd moult. x 12.
Note wing buds.
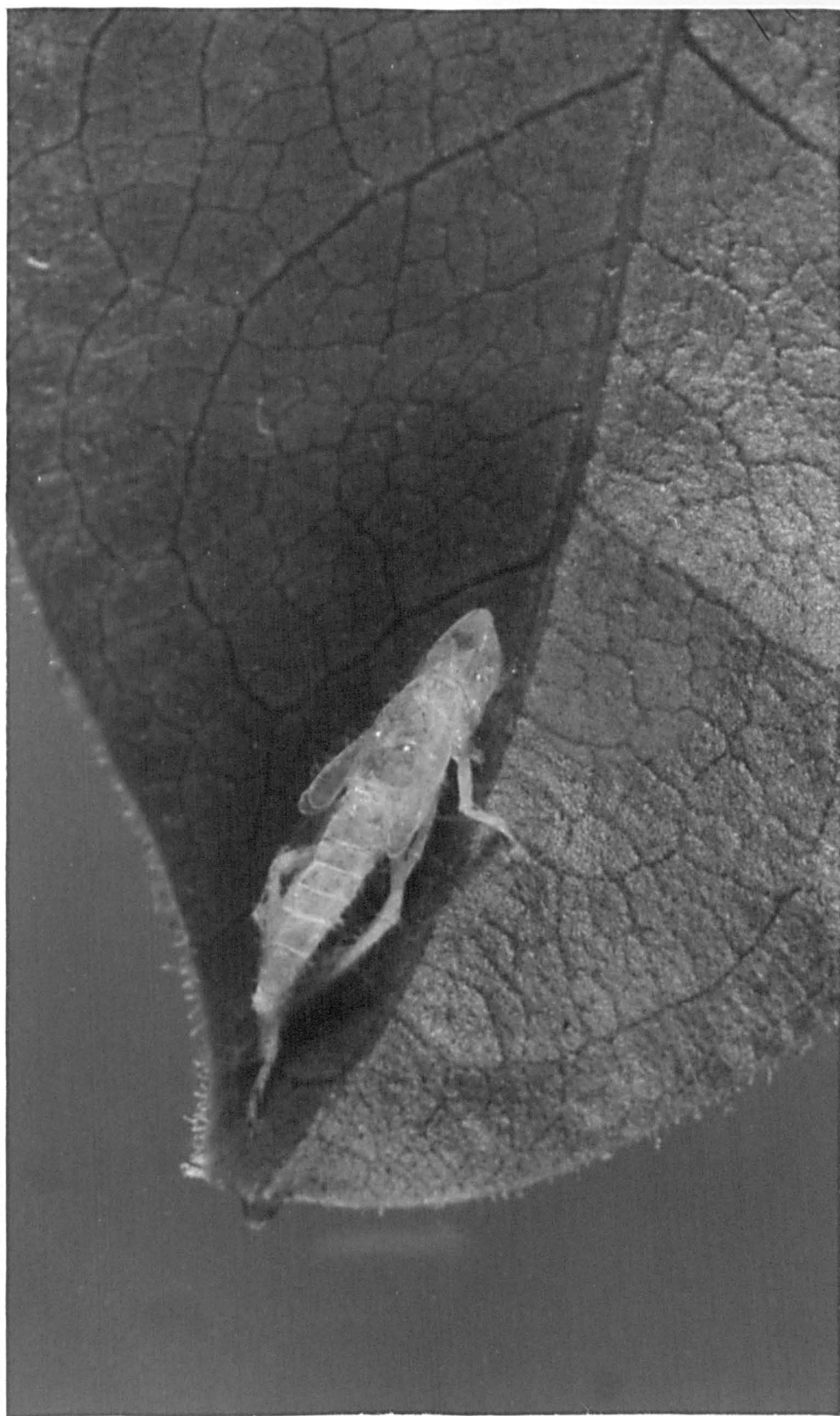
Hind tibiae have row of bristles.

Slender body.   Large eyes.   Suck cell sap.

White shed skins left on leaf at each instar.

Adult: Brightly coloured.   Torpedo-shaped, 5 - 6 mm. long.

Width across forewings 15 mm.   (See coloured diagram).

These are my own observations, which agree with those of
Fox Wilson and Baillie.

LIFE HISTORY OF G. COCCINEA. FORST. ON OUTDOOR RHODODENDRONS

IN GREAT BRITAIN

Baillie (1951) tabulated the life history of this insect in
the field in Great Britain, and a summary follows:-

	Months	Location	Remarks
Eggs	Early August - May	In scars on bud scale, protected by over-lapping scale. Distribution irregular	Eggs perish on outer scales of early flowering vars.
Hatching	May	On bud scales	This date depends on season *
Nymphs	May - June	Running over surface of new leaves	4 Nymphal stages
Adults	July	Inactive until disturbed. On old or new foliage, mainly on upper surfaces	Mature slowly and lay eggs 3 weeks after becoming adult.

(* In the laboratory at Keele in a temperature of 72° F I noted
that nymphs hatched from eggs on 11th March 1962.   These were on buds of

small branches of R. ponticum taken from bushes in Woking, Surrey, the

previous month.   The branches were standing in a cage in water so that

the buds and eggs developed.

It would seem that, if the humidity is kept high, the hatching

of the eggs depends on temperature, a higher temperature accelerating

development of the eggs.)

STATUS OF RHODODENDRON LEAF-HOPPER AS A PEST IN GREAT BRITAIN

Since this pest was introduced to the southern counties of

England forty years ago it does not appear to have spread permanently to

other parts of Britain.   As with the last two mentioned pests, the climate

in the rest of Britain is probably the limiting factor.   It remains to be

seen if the pest will become established in warmer counties, such as

Anglesey, now that it has been introduced on plants from the south of England.

Chemical sprays and resistant varieties can be used in areas

where G. coccinea is found, and so attacks should never become frequent

or severe.

The main reason for recognising and controlling this insect is to

prevent Bud-blast disease being transmitted to unaffected rhododendrons.

In areas where this serious disease is found, regular spraying against

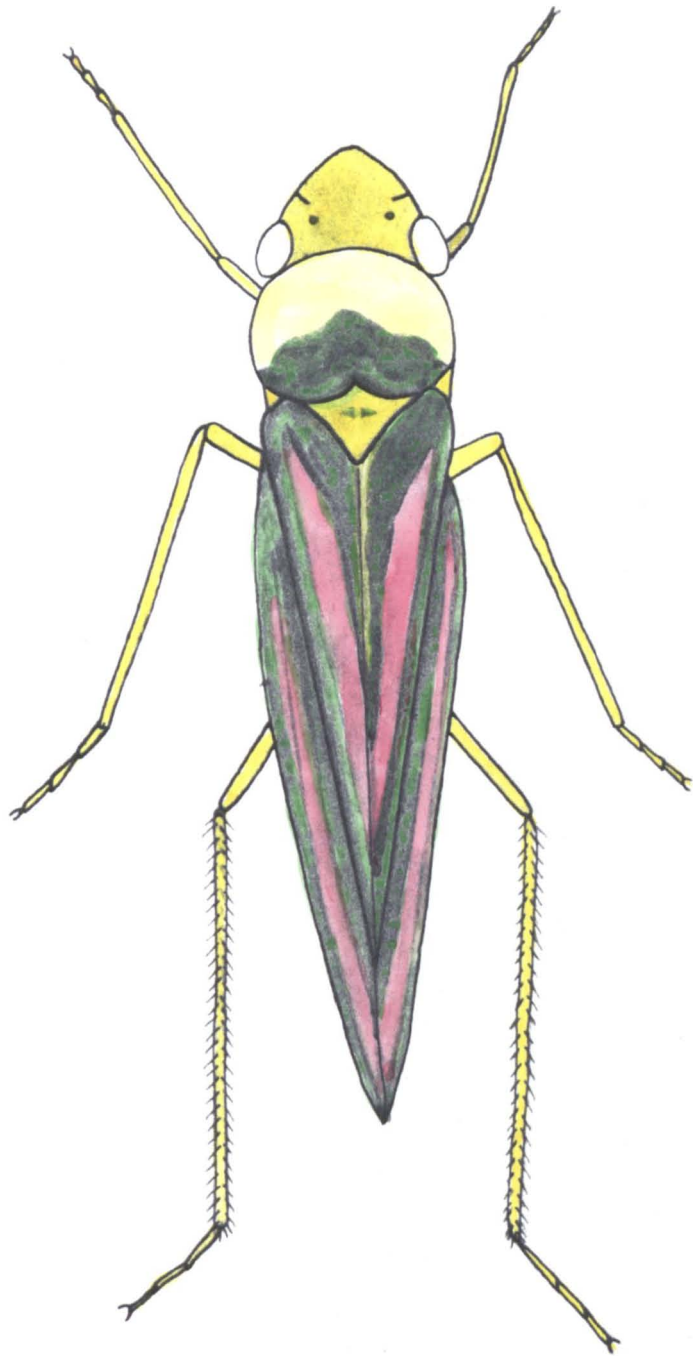G. coccinea should be carried out on commercial nurseries.

Diagram to show colour of adult Rhododendron Leafhopper.

Fig.5

Plate   12.

Rhododendron leaf-hopper.

Adult, side view.   x   24.

Plate   13.

Rhododendron leaf-hopper.

Adult,ventral view. x 16.

AZALEA WHITE FLY

(ALEURODES AZALEAE BAKER AND MOLES)

First recorded in Great Britain in 1931, near Edinburgh.   The
infestation was small.   Plants had been imported from Belgium (Inter. Rev.
1931).   Already described by Essig (1926) in America as occurring on
azaleas imported from Japan and Europe.   By 1937 (Mackie) it had
increased markedly in the U.S.A. and the parasite Encarsia pergandiella
had been noted.

In 1934 (Pescott) the white fly was discovered in Australia on
Rhododendron mucronatum.

It is on the same variety that I have seen the insect outdoors
in 1962 in Surrey.   Although unsightly because of the nymphs and adults
on the back of the leaves, sticky because of honeydew, and indirectly
encouraging sooty moulds to grow, it did not appear to be killing the
small bushes.   Some leaves dropped off the shrubs and no doubt
photosynthesis and respiration were impaired.

From N.A.A.S. records it does not appear to be a common pest
in Great Britain.   In 1962 the only counties to report it to me were
Hampshire, Surrey and Berkshire.

When transported on to bushes of R. mucronatum in Staffordshire,
the insect died out during the same year.   I would presume that this
was due to the colder, damper climate than in other places where it is
found.   It is normally imported and often, when found, on plants grown
in glasshouses (as was the first record in Great Britain (Deshpande 1930)).

Distribution of Aleurodes azaleae

in the counties of the British Isles.

▨ Present as pest.

▨ Found only on imported plants.

1. Hampshire   3. Surrey
2. Berkshire   4. Border counties
        5. Edinburgh district.

Fig 6.

The symptoms and damage to the plant and the life cycle are similar to those described under Rhododendron White Fly.

Deshpande (1933) described the anatomy of some British Aleurodidae and included Aleurodes azaleae.

In the U.S.A. Aleurodes azaleae is hardly ever mentioned as a pest of azaleas. The common whitefly on azaleas in that country appears to be Tetraleurodes mori Quaint., the Mulberry Whitefly (Kerr 1959; Weigel and Baumhofer 1948).

CONTROL.

Spray undersides of leaves with derris and pyrethrum, or with nicotine sulphate and soft soap. Two or three applications at weekly intervals.

1 pint white oil and 1 oz. nicotine sulphate in 5 gallons of water can be used (Pescott 1943).

More modern insecticides, mentioned under Rhododendron Whitefly control, should also control A. azaleae.

PRESENT STATUS AS A PEST IN GREAT BRITAIN

Aleurodes azaleae is found only infrequently on outdoor bushes (particularly R. mucronatum), and sometimes on imported plants grown in greenhouses. It is not a serious threat to the rhododendron industry and can be easily controlled.

APHIS ON RHODODENDRONS

On the rhododendron, aphids are not a troublesome pest in Great Britain.

Masonaphis rhododendri Wilson, Myzus ornatus Laing., have been recorded on imported R. (A) indicum.

Miles (1935) mentions Myzus circumflexus Buck. on the same plant in glasshouses.

During these studies I have never observed aphids doing any appreciable damage to rhododendrons outdoors in England or Wales. There have been some records of Masonaphis rhododendri in the U.S.A. (Pirone, Dodge and Rickett 1960), also Macrosiphum rhododendri (Westcott 1946).

LEPIDOPTEROUS PESTS OF RHODODENDRONS

The moths shown in the following list (page 58) have been found on the leaves of outdoor rhododendrons at Keele and Willoughbridge during the years 1961-65.

The tortrix moth caterpillars appear to cause more damage than the others, due to their being present in larger numbers. They roll the leaves and eat within a finely spun web.

Some tortrix caterpillars have been found on R. ponticum and other smooth-leaved varieties or species, especially on the young unfolding leaves, but the majority of these pests are found on the glaucous leaves which have an indumentum on the lower surface. This may be because it is physically easier for the caterpillar to attach itself, with or without a web, on to a leaf having a hairy surface rather than a glabrous one, or that the smooth leaves, being different in texture, may be more difficult to fold or roll.

The smell of the leaves, too, may attract some caterpillars. Many tortrix moths were found on a bush which bears pungent leaves at Willoughbridge (variety unknown) and caused a great deal of unsightliness (Plate 16). This bush was not directly under, nor particularly near to any oak trees in the garden, and it would appear from this and other similar observations that the Green Tortrix (Tortrix viridana L.) is now a pest of rhododendron directly, and not just a chance host for caterpillars which fall from the trees above (Fox-Wilson 1925).

Irregular holes are eaten in the leaves by caterpillars,

Plate 14.

Tortrix viridana. x 10.

Larva and adult on rhododendron leaf.
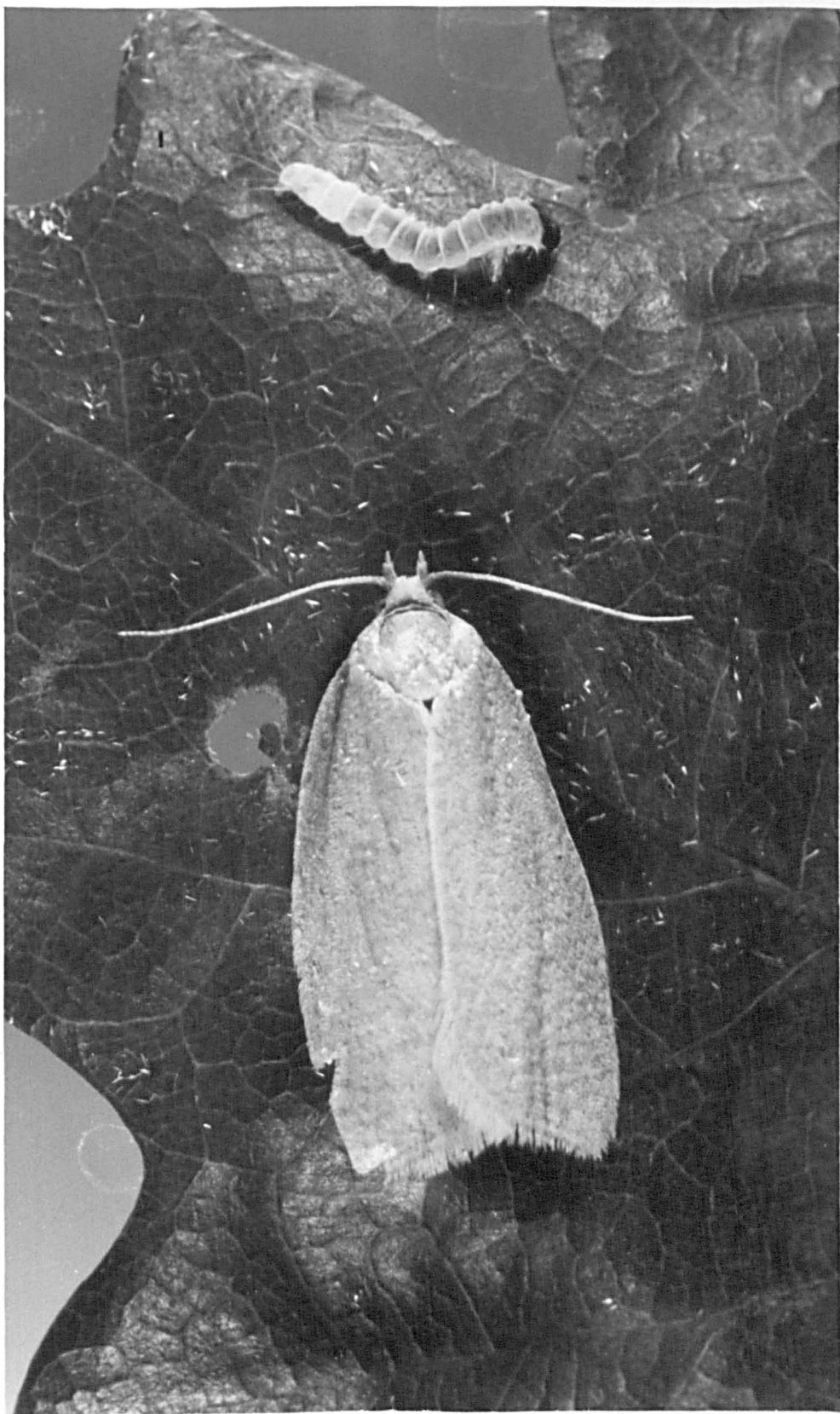
a. Damage to old leaf x $\frac{1}{2}$.

b. Larva feeding on new leaf
    (note webbing and excreta)
             x 5.

c. Twisted leaves with webs of Tortrix sp.
             x $\frac{1}{2}$.

Plate 15.

Plate   16.
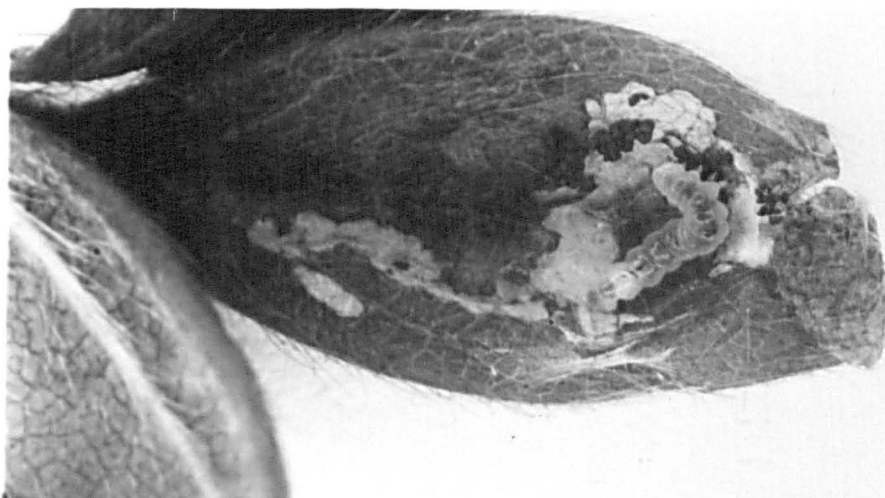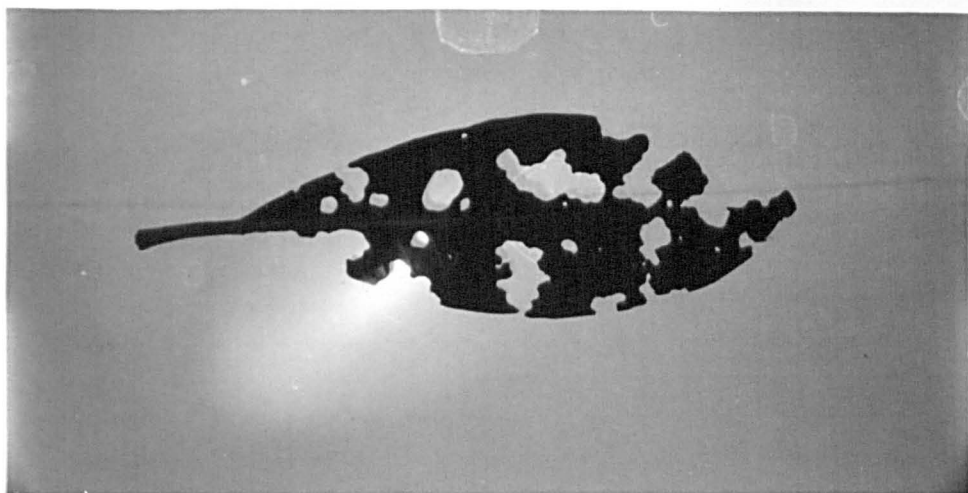
Caterpillar damage.

a.   Angle shades moth larva eating young leaves and
flower buds of outdoor azalea.

b.   Damage to fragrant leaves of rhododendron variety
with thick indumentum.

both along the margin and further in towards the midrib.   The petiole

and midrib are usually left uneaten.

The Geometrid, Dotted Border (<u>Erranis progemmaria</u>) care-

fully left the midrib and the epidermis at the margin of the leaf all

the way round when fed on <u>R. ponticum</u> in the laboratory.

Apart from the tortrix mentioned, the other moths and their

larvae were only found on odd occasions and can hardly be considered as

pests.   Fox-Wilson (1925) found rather different species from those

found by the author; this may be due to the geographical locations of

the collections, as he worked in the southern counties of England rather

than the northern.

Photographs of some of the Lepidopterous pests are shown.

CONTROL

(a) Can be handpicked

(b) Spray bushes if a large attack is noticed in the nursery.

Spray early because the Tortrix larvae roll leaves around themselves.

Derris, Trichlorphon or DDT can be used, but the latter is not now

(1970) advised.

Table v.   LEPIDOPTERA FOUND ON RHODODENDRONS AT KEELE

Name	Family	English name	Date	Stage
Scoliopteryx libatrix (L.)	Catocalnae	Herald moth	Sept.	Imago
Agrotis segetum (Schiff.)	Agrotinae	Common Dart	July	Imago
Bena prasinana (L.)	Cymbidae	Green Silver Lines	July	Imago
Tortrix viridana (L.)	Tortricidae	Green tortrix	June July	Larvae, pupae & imago
Pandemis cerasana (Hueb.) (syn. P.ribeana)	Tortricidae		July	Larvae, pupa & imago
Hepialus humuli (L.)	Hepialidae	Ghost moth	July	Imago
Adela reaumurella (L.)	Adeilidae	Green longhorn moth	June	Imago
Agrochola macilenta (Hueb.)	Dasypoliinae	Yellow line Quaker	Sept.	Imago
Trichopteryx poly-commata (Schiff.)	Hydriomenidae	Barred tooth-striped	April	Imago
Erannis progemmaria (Huebner)	Selidosemidae	Dotted border	May April	Larva Imago
Melanchra persi-cariae (L.)	Caradrinidae	Dot Moth	Sept.	Larva
Plusia chrysitis (L.)	Plusiinae	Burnished Brass	May	Larva
Phlogophora meticulosa (L.)	Caradrinidae	Angle-shades	August	Larva

AZALEA LEAF MINER

(GRACILARIA AZALEELLA BRANTS.)

Not a common pest, but sometimes found on azaleas, especially on A. indica in glasshouses.

HISTORY

This Tineid moth is a native of Japan and probably came to Britain in 1925 via Holland or Belgium (Hodson 1927). The next year it was seen on outdoor azaleas in Exeter. About the same time it became a pest in the U.S.A., where it is now of more importance and more common than in Great Britain.

DAMAGE CAUSED

The leaves are mined by the young larvae feeding under the epidermis. Tunnels are seen, leaves turn yellow, brown, and some shrivel and die, and fall. As the larvae move on from leaf to leaf, they become fully fed and then emerge to construct cocoons under the rolled tips of leaves. When the adult emerges from the cocoon, the empty pupal case is seen protruding. Damage is most evident from November to March in warm glasshouses on imported plants.

LIFE HISTORY (after Hodson 1927):

Adult moth can be seen flying about in an infested house, usually in late autumn. They have about a 5 mm. wingspan; yellow and grey in colour, and are very active.

The eggs are oval, flattened, shiny and are laid singly on the underside of the leaves, about five to a leaf.

<u>Larvae</u> hatch after four days.   They are minute 0.6 mm., transparent, with visible legs.

They immediately enter the leaf and here undergo several moults, becoming 5 mm. long, yellow-brown with normal lepidopterous legs.

<u>Pupate</u> inside cocoon on leaf under rolled tip.   Pupa is greenish yellow turning brown, about 5 mm. in length.

There may be several generations a year.

CONTROL

(a)   On a small scale, infected leaves can be hand picked and burned.

(b)   Spray the leaves with malathion or DDT[x] (Kerr 1959).

(c)   Thimet has been used for several leaf miners (Schread 1959).

I have never seen this pest on outdoor rhododendrons in Great Britain, only on glasshouse azaleas.

PRESENT STATUS OF LEPIDOPTEROUS PESTS ON RHODODENDRONS IN GREAT BRITAIN

Apart from the <u>Tortricidae</u> and <u>G. azaleella</u>, the effect of caterpillars on rhododendrons is negligible.

<u>Tortrix</u> moth larvae cause some appreciable damage to glaucous rhododendron leaves, which they roll and disfigure by eating the lamina.   Unlike the previously mentioned pests, <u>Tortrix</u> moths are found in the Midlands and North of the country, as well as in the south, but not in large enough numbers to make them a serious pest.

x   DDT not now advised (1970)

Azalea leaf miner is normally only a pest on imported plants in glasshouses.

Both can be controlled by hand-picking infected leaves or by spraying the shrubs with the appropriate chemical.

COLEOPTEROUS PESTS OF RHODODENDRONS

Several species of beetles and weevils attack the leaves
and flowers of rhododendrons in Great Britain and cause characteristic
damage.   Some of these insects and their damage are described below.

DAMAGE

Damage, such as that shown in Plate 17 can be seen to some
extent on almost all rhododendron plants grown outdoors (as well as on
many other decorative garden plants and weeds, Schofield (1962) and on
fruit trees and bushes, Massee (1945).   The eaten portions are irregu-
lar, beginning at the margin of the leaf.   Old damage is surrounded
by dead, brown patches.

Wilson (1939) stated that in the south of England, this
damage was caused by the vine weevil, _Otiorhynchus sulcatus_ F., but in
my experience in north Staffordshire and many other counties, far
greater numbers of the clay-coloured weevil, _O. singularis L._, can be
found on the bushes and the damage done by both species is similar.
Sometimes they are found feeding together on the same bush, but always
I have found many more of the latter than the former.   Both feed more
on the smooth-leaved varieties of rhododendron, and also on deciduous
azaleas, than on the rhododendrons having a thick pubescence on the
under surface of the leaf.   _O. singularis_ attacks _R. ponticum_ more
commonly than other kinds of rhododendron.   I have noticed that bushes
adjacent to Yew, _Taxus baccata_, seem especially prone to attack by
O. singularis, but I could not find the insect in the soil immediately

Plate   17.

a.   b.

Damage to rhododendron leaves   x $\frac{1}{2}$ by:

    (a).   Otiorhynchus sulcatus.

    (b).   Otiorhynchus singularis.

Plate 18.
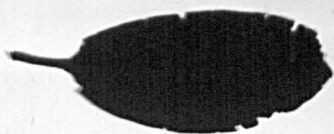
O. singularis.   O. sulcatus.

Strophosomus melanogrammus.   Serica brunnea.

Damage to Rhododendron leaves by coleopterous pests.

around the Yew trees.

The clay-coloured weevil, as recorded by Wilson, will eat into the petioles of the rhododendron and cause the leaves to wilt and die, but so also will the vine weevil. The holes in the centre of the leaves mentioned by Wilson (1925) are most probably due to caterpillars or to the beetle Serica brunnea(L.) mentioned below, and not to O. singularis. After observing the above weevils for many years, I have not seen them causing holes away from the margin of the leaf (except on rare occasions when the leaf was folded back on itself, or was stuck to the edge of another leaf).

Another weevil, sometimes known as the nut leaf weevil, Strophosomus melanogrammus(Forst.), eats regular, smaller holes along the leaf margins, not penetrating far in towards the midrib. I have not seen Strophosomus eating the epidemis in the centre of the leaf as described by Fox-Wilson (1925, 1933); this damage is normally caused by Tortrix and some other caterpillars.

Although most of the holes in the rhododendron leaves away from the margins are caused by moth caterpillars (especially in oak woods and on the thick, hairy rhododendron leaves), I have observed the sandy-coloured, adult chafer beetle Serica brunnea(L.) eating small, round, fairly regular holes in the leaves, on bushes after dark in July. They also caused this type of damage when kept in the laboratory. These beetles were not common, however, and I have never found more than six in a summer at Willoughbridge. They have not been recorded

on rhododendron before.

The damage caused by the last four named coleopterous pests can be seen in Plate 18.

Damage caused by a larger chafer beetle, the cockchafer or May bug, Melolontha melolontha (L.), is perhaps even more dramatic to see. The beetle devours irregular pieces of the rhododendron and even whole flowers, Schofield (1964), and jagged indentations can be seen along the bitten edges with heavy excrement fouling the leaves and flowers (Plate 19).

The brilliantly coloured weevil Phyllobius pomaceus Gyll. has sometimes been seen on rhododendron leaves, but, as described later in an account of a small laboratory experiment, does not appear to damage them, preferring to eat stinging nettles (Fig. 9).

Most of the damage described above is caused at night, and the insects concerned are not often seen by the gardener or horticulturist unless he searches his bushes by torchlight after dark, or examines the soil and litter around the plants during the day. Sometimes the cock-chafer and the small chafer rest on the branches during the day, but the weevils hide in the soil.

Larvae of some coleopterous insects, including the wireworm Agriotes obscurus (L.) and the cockchafer M. melolontha, and of the weevils Otiorhynchus singularis and O. sulcatus, were also found in the soil around rhododendron bushes, but I saw nothing to suggest that they were directly harming the plants, although it is known that these larvae will feed on plant roots.

DESCRIPTION, LIFE HISTORIES AND CONTROL OF SOME COLEOPTEROUS PESTS

1. THE CLAY-COLOURED WEEVIL, OTIORHYNCHUS SINGULARIS (L.)

As this was by far the commonest pest found in Staffordshire, a full description and many experiments dealing with this insect will be found in Part II.

The weevil is about 7 mm. long, light brown, with hairs and golden scales on the fused elytra. Often soil adheres to the back of the weevil, camouflaging it still further.

Both O. singularis and O. sulcatus (described under 2) have long rostra in front of their heads, with elbowed or geniculate antennae arising from scrobes; also a typically toothed femur on the fore legs. Both are flightless and parthenogenetic, no males of the species ever having been found in Britain. The weevils lay white eggs which darken and develop into tiny, white, legless larvae and after six instars change into white, soft-bodied pupae. All these stages are in the soil. The adult weevils emerge from the soil about May, feed on the leaves of plants until September or October, eating only after dark. The vine weevil comes out of hiding in the soil at dusk, slightly earlier than the clay-coloured weevil which appears to prefer more intense darkness, or maybe a lower temperature (see factorial experiment, Part II).

2. THE VINE WEEVIL, OTIORHYNCHUS SULCATUS (F.)

Fuller morphological details of the adult are given in
Part II. The weevil is black, about 1 cm. long (Pl.30). The
whitish hairs on the fused elytra and thorax are fine and short.

This weevil is a pest on many plants, and much damage is
done to the roots of pot plants in glasshouses by the larvae which
reach 1 cm. in length (M.A.A.F. leaflet No. 57). Several of these
larvae could no doubt do considerable damage to the roots of small
rhododendrons in nurseries or in pots, but the numbers of vine weevils
in the Midlands is so low that it is not liable to prove more than an
occasional nuisance in this part of Britain. In the south of England
where the temperature is on the whole higher, the vine weevil may be
more common (even more common than the clay-coloured weevil, though I
have never witnessed this), and could then become a major pest in rhodo-
dendron and azalea nurseries.

HISTORY AND CONTROL

As far back as seventy years ago in Britain, Muller (1894)
showed leaves of R. ponticum and Gaultheria shallon which had been eaten
down to the midrib by this weevil.

By 1912 MacDougall wrote of O. sulcatus being a pest of pot
plants in Scotland, and during the following ten years there are innumer-
able references to this weevil, e.g. on rhododendron and yew in Holland,
on strawberries in Oregon (Lovett 1913) and in France (Verdier 1913).
It is recorded in the Rev. of Applied Entomology from U.S.A., Britain,

Canada, France, Italy, Ireland, Germany, Sweden, U.S.S.R. during the years 1913 - 1916. Also during these years, horticulturists were searching for a control, and these included soaking the pots of soil in water to drown the larvae; CS_2 injected into the ground in autumn; sticky bands on trees to prevent the flightless weevil from walking up; bitter aloes in a copper spray; tufts of wood wool between the plants for the weevils to hide in during the day (I have tried this method in Staffordshire without success), and a spray of 1 oz. Paris green with 2 lb. lime in 19 gallons of water.

Due to being a pest of vines in France, O. sulcatus has been much studied. Feytaud (1914) wrote on the life cycle and damage caused and in 1916 a syndicate was formed at Ile d'Oleron to collect by hand 1,400,000 weevils before oviposition in the vineyards. (Feytaud 1916, 1917, 1918). This brilliant idea for biological control using humans was successful at first, but by 1925 Feytaud was writing of "Le traitment arsenical contre les Otiorhynques" because the pest was on the increase and chemical methods were being sought. The hand-picking had been expensive and the outbreaks scattered and difficult to reach.

In 1920, Frank suggested control of O. sulcatus by placing saucers 5' apart containing two-thirds oz. CS_2 under a canvas painted with linseed oil, which also covered the affected strawberry plants, and Thiem (1922) wrote on the biology and control of O. sulcatus. Smith (E.L.) (1927) reported from California that the weevil was eradicated

from greenhouses by means of shallow troughs of crude oil. Anderson
(1929) controlled the pest in Primula houses by hand sorting of the
soil for larvae, then applying crude flake naphthalene to the soil.
Mote and Wilcox (1927) describe in great detail the preparation of
arsenical baits based on ground apple. Besides using arsenic, Smith
(F.F.), (1927, 1930, 1932) suggests that weeds near greenhouses be kept
down, as O. sulcatus feeds on these also.

In 1928, Tempel wrote of O. sulcatus as a pest of Azaleas
in Germany and suggested that the insect was introduced into the pots
through the peat which should first be stored outside. Around 1930,
the biology of the weevil was further studied (Hodson and Beaumont 1931,
Thiem 1932), and other controls of sodium fluosilicate (Smith, L.M.,
1930) and naphthalene in carbon bisulphide (Krauss 1931) were tried.

The first report of an Otiorhynchus sp. infesting dwelling
houses was in 1934 from Connecticut, and I have noticed O. sulcatus
often indoors in private houses in summer and autumn, apparently harm-
less.

It is interesting that in 1935 Zillig wrote that O. sulcatus
was now only a rare pest on vines in Germany, due to the use of arsenical
insecticides.

By the 1940's, vine weevil was being mentioned mostly as
a pest of ornamentals and soft fruits such as strawberries and rasp-
berries (Scott 1942, Schread 1951). Controls now included Parathion,
BHC and Chlordane for killing the larvae in the soil. Hamilton (1953)

mentions Heptachor and Aldrin also.

The M.A.F.F. Advis. Leaflet 57 advises control by Aldrin, DDT, BHC and Malathion. Unless a large epidemic is imminent, I would advise hand picking of larvae from soil and of adults from plants at night.

Natural enemies include Carabid, Staphylinid beetles and Cerceris wasps (Feytaud 1914), poultry, toads, shrews and hedgehogs (Feytaud 1918), starlings (Kalmbach and Gabrielson 1921) and field-fares (Meidell 1937).

3. THE COCKCHAFER BEETLE, MELOLONTHA MELOLONTHA (L.)

Much has been written about this large chaffer beetle (Kevan 1962; M.A.F.F. leaflet 235; Lebeneweine 1939; Jones and Jones 1964), and it is mentioned in most books on garden pests (Schofield 1964), probably because it is a large, showy insect and spasmodically appears in swarms.

The adult is about 24 mm. long with large striated, brown elytra over powerful flying wings. The antennae are distinctive, being lamellate and reddish brown.

The eggs are laid in the soil, about 8 inches deep and in batches of 15 or more, during early summer. They hatch after about 3 - 6 weeks and the fleshy, white larvae take three years to be fully grown in Great Britain. The life cycle may be shortened in warmer climates (Imms 1957). The larva can reach 6 cm. but is normally bent into a C-shape (Fig. 7).

When mature, the larvae burrow down to around 2 feet (60 cm.) in the soil and pupate in an earthen cell.

Although the pupa changes into an adult by late autumn, it remains in the cell in diapause until spring.

The adult emerges in May four years after the egg is laid. Mating takes place between the males and females whilst at rest on the bushes, and eggs are laid about three weeks after emergence.

Two female, adult Cockchafer Beetles were found, one on May 31st and the other on June 8th, 1962, both on flowers of rhododendrons variety "Pink Pearl" during the daytime, in the garden at Willoughbridge.

Plate 19.

Damage to rhododendron leaves and flowers

by M. melolontha.

2·3 cm.
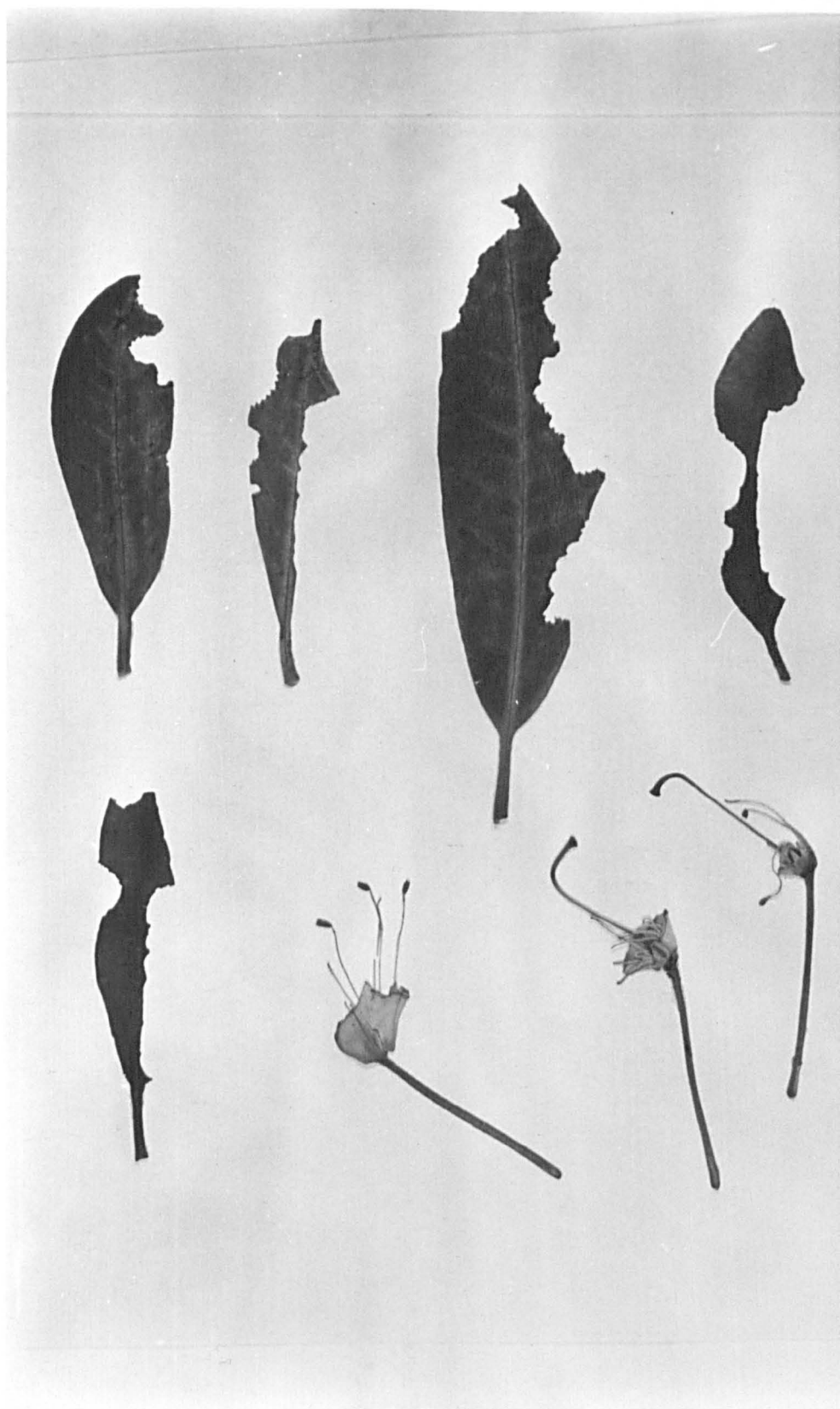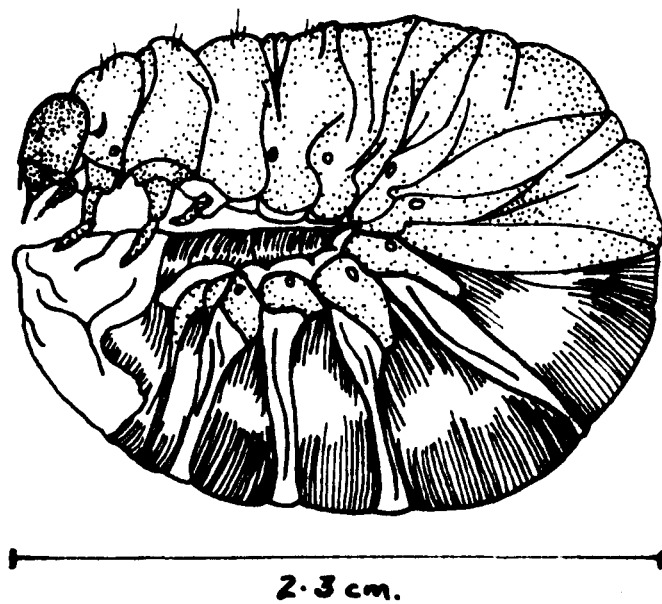
Larva of Cockchafer Beetle.

Fig 7.

1 cm.
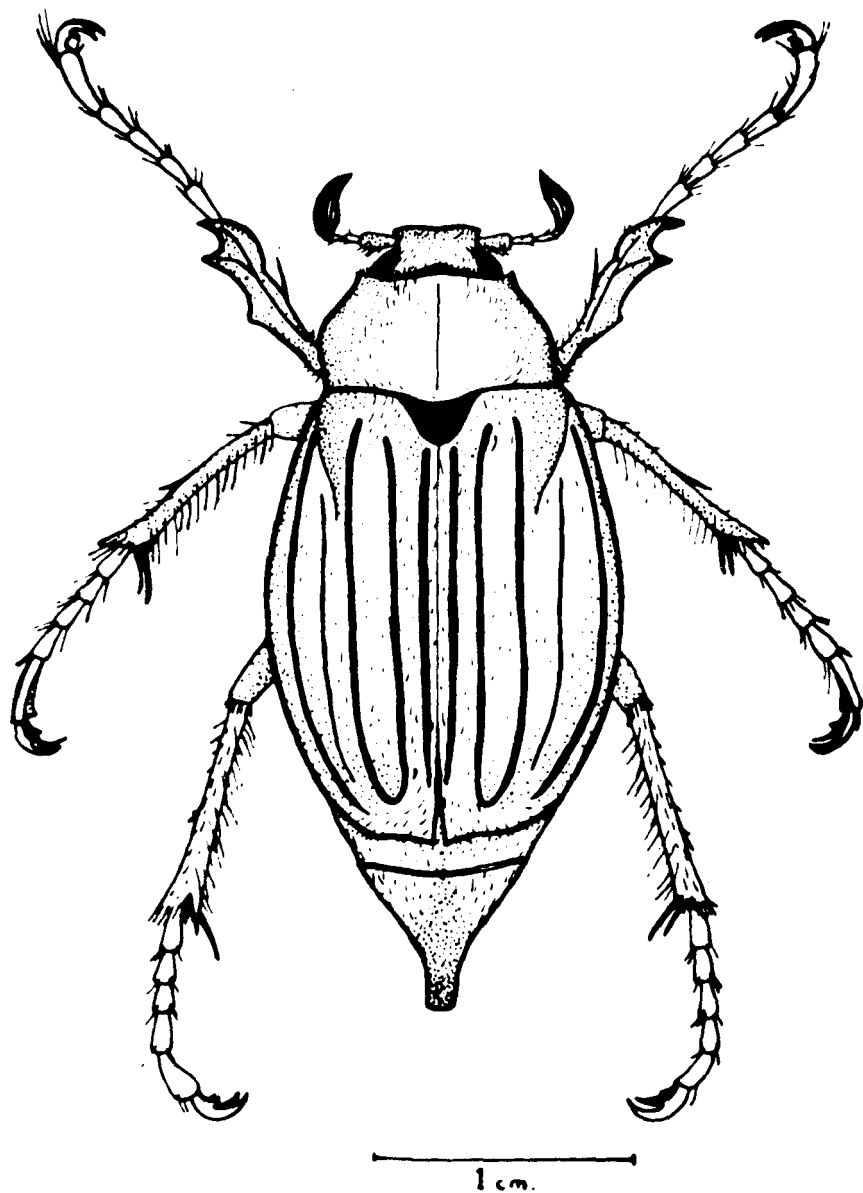
Adult Cockchafer Beetle.

Fig 8.

They were picked off by hand and kept in a cage in the laboratory with rhododendron shoots and flowers until July 17th and 24th, when they died without producing eggs.

One beetle, which was very slightly larger than the other, ate the petals and anthers of the flowers, but not the stigma, down to the ovary. This one did not eat the leaves. The second beetle ate the laminae of the new leaves down to the petioles, and ate the edges of old leaves but was not observed eating the flowers.

In both cases there was much fouling of the flowers and leaves by the heavy excrement. Both beetles ate voraciously both by day and night, and in the morning were often buried in the soil or on the soil surface.

CONTROL

(a)   Hand-pick adults from bushes

(b)   DDT or BHC in soil to kill grubs

(c)   DDT spray to bushes, applied quickly. DDT should not now be used (1970) unless absolutely necessary.

The cockchafer beetle has many natural enemies including rooks, starlings, thrushes, gulls, owls, nightjars and bats.

4. STROPHOSOMUS MELANOGRAMMUS (FORST.)

Known sometimes as the nut leaf weevil, this small brown beetle is shown in Plate 20. It is 0.5 cm. long with a short, blunt rostrum and protruding eyes. It eats the leaves after dark and the immature stages are found in the soil. Stringer in 1959 wrote that he found three species of Strophosomus attacking rhododendrons in Ascot, namely S. melanogrammus, S. capitatus, and S. sus (the latter in smaller numbers). The ones I found at Willoughbridge, Keele and at Coombes Valley, Derbyshire were all apparently S. melanogrammus (syn. S. coryli Fab.) and all were noticed in August.

More common hosts for this weevil are oak, hazel and birch. It was first mentioned in "The Garden" in 1888 as attacking rhododendron leaves in Sunningdale.

TYPE OF DAMAGE

This consists of small, regular bites along leaf edge, not skeletonizing leaves as described by Fox-Wilson (1949). The damage is not easily confused with that caused by other weevils, because the holes are smaller and usually only in about 2 mm. from the outer edge of leaf (see Plate 21).

CONTROL

According to Stringer, control is obtained by one application of 25 per cent miscible DDT at 2 pints per 100 gallons.

<u>Plate 20.</u>

<u>Strophosomus melanogrammus</u>

a. Damage to R. <u>mucronatum</u>
    leaves. (<u>Small-leaved</u> species). **x** 2.

b. Adult Weevil. × 8
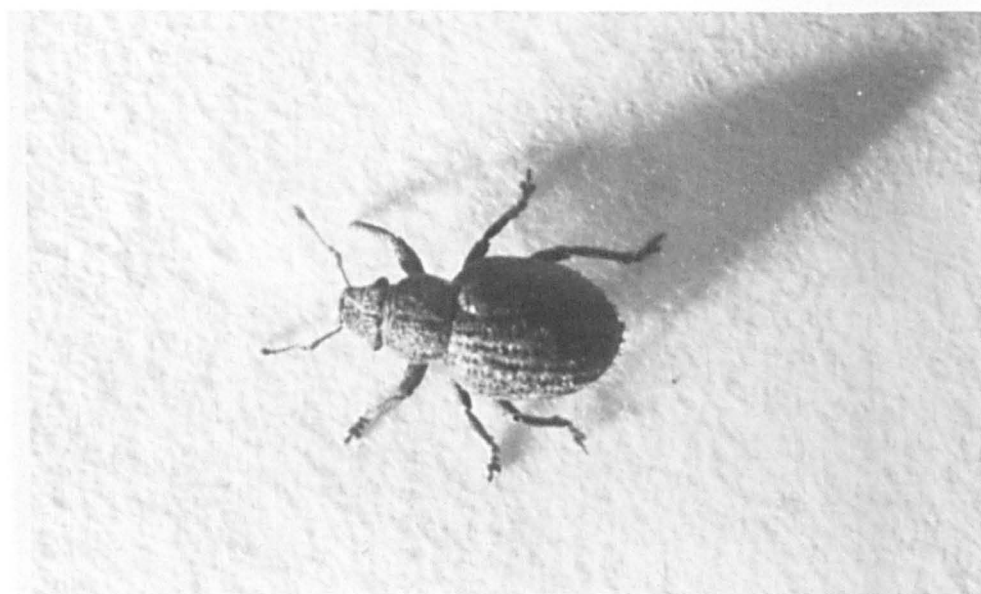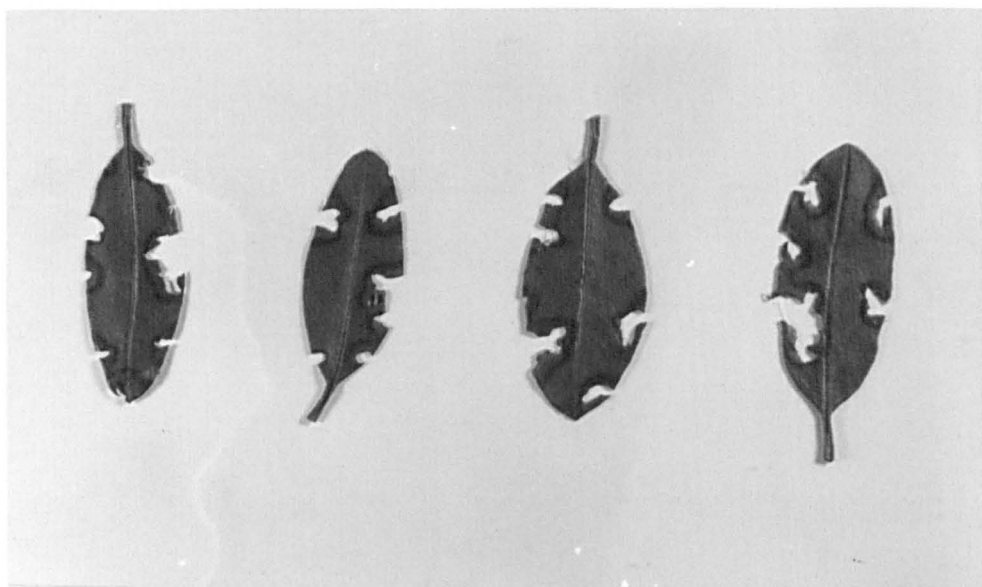
<u>Plate   21.</u>

Damage to rhododendron leaves

   by <u>S. melanogrammus</u>   x $\frac{3}{4}$.

This shows typical damage to

rhododendrons in general.
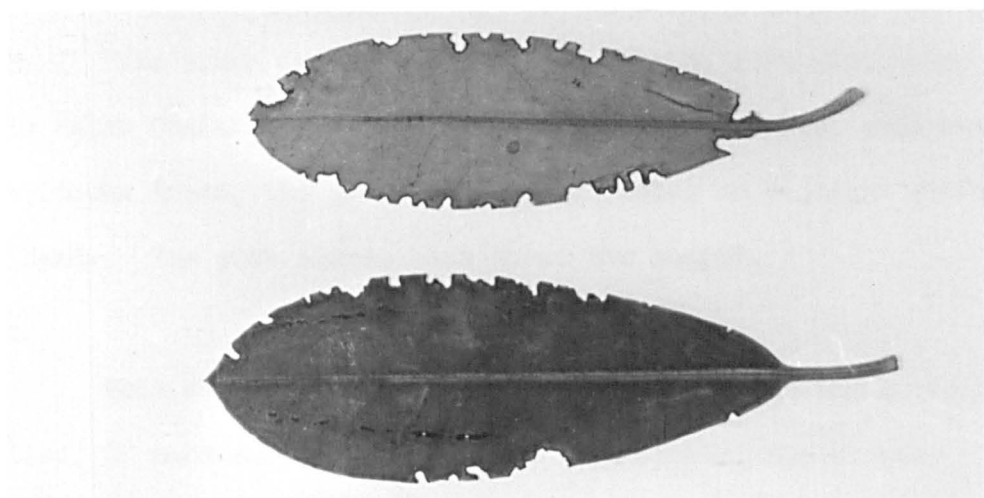
5. <u>SERICA BRUNNEA(L.)</u>

The sandy-coloured, chafer beetle is 1 cm. long and 0.5 cm. broad. The elytra are broad and straight, almost completely covering the abdomen (Plate 22).

The flying wings are strong. It has large, round, dark eyes, protruding slightly at each side of the head. The antennae are lamellate with three club segments.

The M.A.R.F. Advisory Leaflet No. 235 states:

"The Brown Chafer (<u>S. brunnea</u>), though more widespread than the Welsh Chafer, is common only in a few localities, well-wooded with deciduous trees, the grubs being troublesome on adjacent grass and arable land. The grub stages last about two years".

<u>CONTROL</u>

This was not a common pest on rhododendrons and could be controlled, if necessary, by hand-picking or shaking the bushes. Many birds eat the chafer grubs.

Plate 22.

Serica brunnea and the damage on

rhododendron leaf.
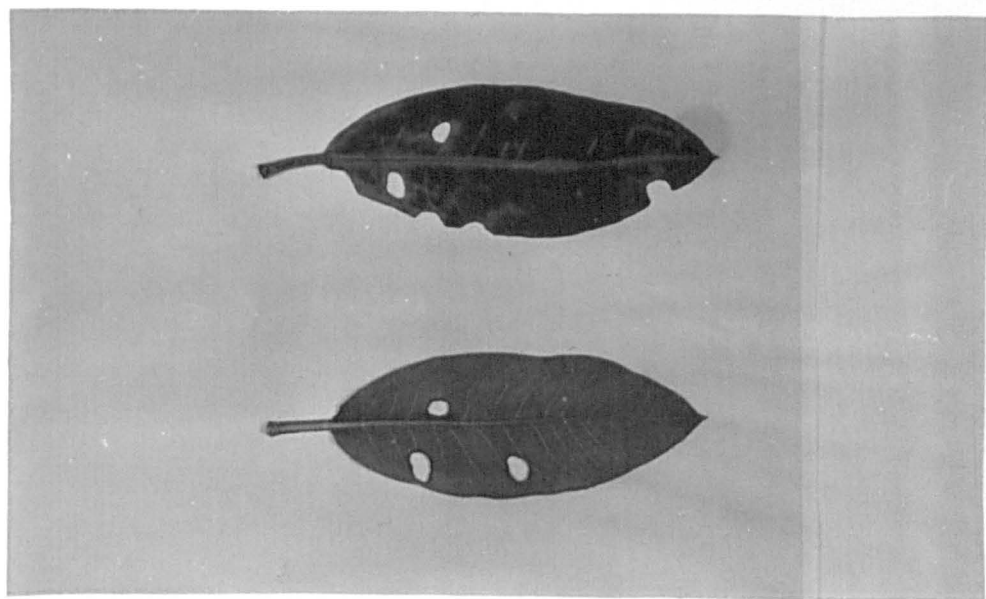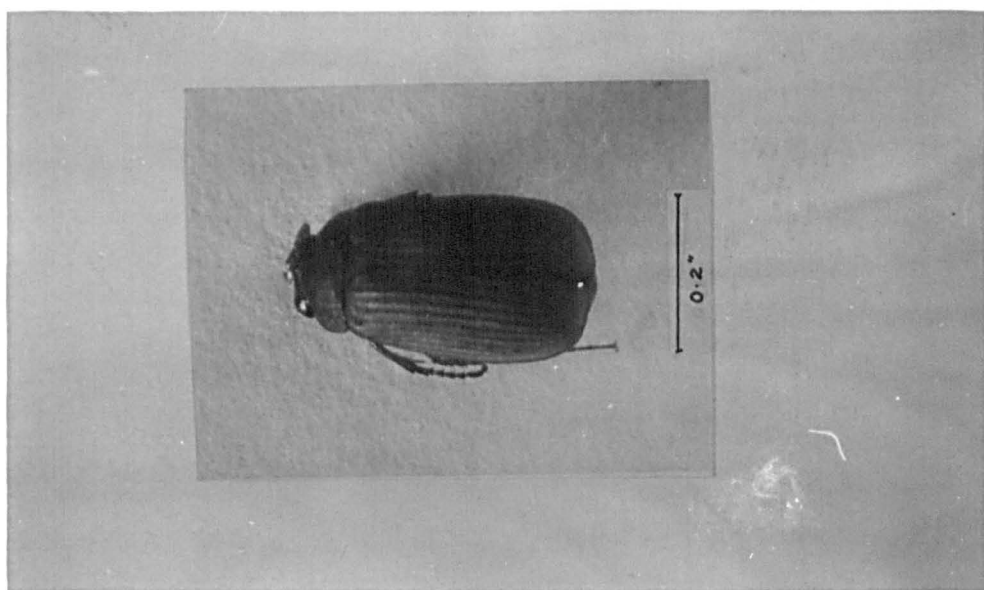
6. PHYLLOBIUS POMACEUS GILL.

This weevil was found eating the leaves of nettles, which were growing through the rhododendron bushes, both by day and night. It was active in sun, shade or dark, but not apparently in windy weather.

Many were pairing, the male being smaller and greener, the female more golden-green.

Some were seen on the leaves of rhododendron and, to discover whether rhododendron was a host plant, the following test was carried out in the laboratory in June, 1962.

Jar 1:   Weevils + nettle shoots alone

Jar 2:   Weevils + nettle and rhododendron

Jar 3:   Weevils + rhododendron alone

Results showed that in Jars 1 and 2 the nettles were eaten, but not the rhododendron in Jar 2.   In Jar 3 the weevils ate the new rhododendron leaves, making small holes (Fig. 9)

The conclusion reached was that, although P. pomaceus (syn. P. articae and P. alneti) would eat rhododendron leaf if no nettles were available, they are not endemic on these plants.
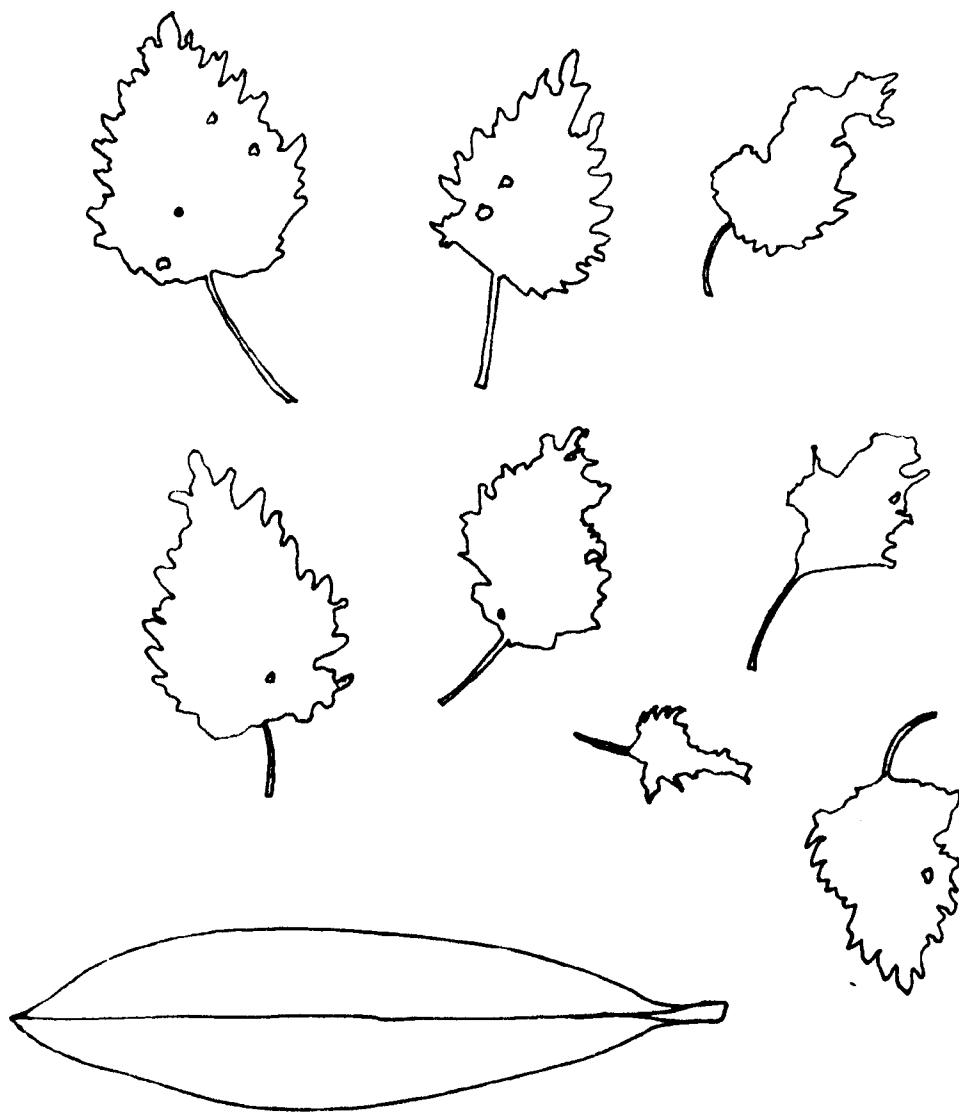
Nettle leaves damaged by weevil _Phyllobius pomaceus._ Rhododendron leaf unbitten. x ¾.

Fig. 9

PRESENT STATUS OF COLEOPTEROUS PESTS ON RHODODENDRONS IN GREAT BRITAIN

None of the pests in Coleoptera, just mentioned, is in such great numbers or causes so much damage that fully-grown rhododendron bushes would be killed, but some of them can cause disfigurement and even prove lethal to small nursery plants.

Holes in the leaves caused by the two Otiorhynchus species can be particularly unsightly on young plants, O. singularis being very active in the midlands and north of England and Wales. O. sulcatus larvae might also damage the roots of newly rooted cuttings and nursery stock.

The Cockchafer beetle attacks spasmodically and in some years much damage can result to both flowers and leaves.

Strophosomus melanogrammus can also cause much unsightly damage to the margins of leaves and render young plants unsaleable.

Serica brunnea is only an occasional pest and the weevil Phyllobius pomaceus can be disregarded.

HYMENOPTEROUS PESTS OF RHODODENDRONS

1. LEAF-CUTTER BEES

Megachile species (leaf-cutter bees) sometimes attract attention by cutting circular or semi-circular areas from leaves, including those of rhododendrons (Pl. 23).   There are nine species of Megachile found in Great Britain.   The pieces of leaves are used in forming a thimblelike brood-cell for larval bees in broken ends of branches, old stems of plants, or in holes in the ground.   Most of the leaf-cutter bees are about 1.3 cm. long, similar to a honey bee, black and yellow, but with a broader head (Imms 1947).

CONTROL

Nests and all infested shoots can be destroyed.   The damage is usually slight, and not serious enough to cause permanent injury to the rhododendron plant.

2. SAWFLY ON RHODODENDRONS

Two larvae of an unidentified sawfly were found on leaves of R. ponticum at Willoughbridge (Pl. 23).   In the laboratory, they ate along the margin of the leaf.

Sawfly has not been reported as a pest of rhododendrons in Great Britain, but some species have been reported from China, Japan and the U.S.A.

Plate 23.
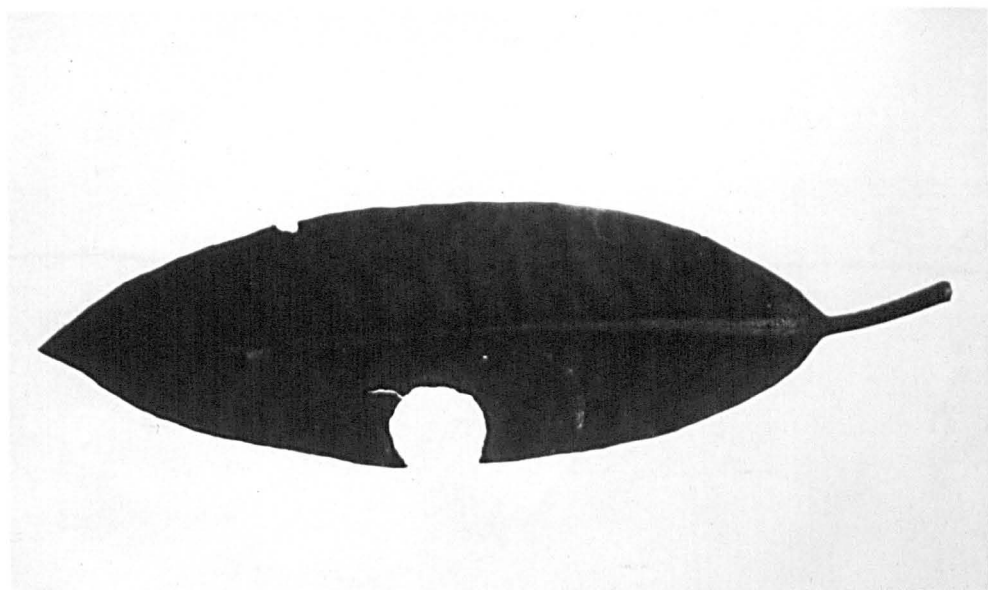
a. Leaf-cutter bee damage on rhododendron
leaf. x 1
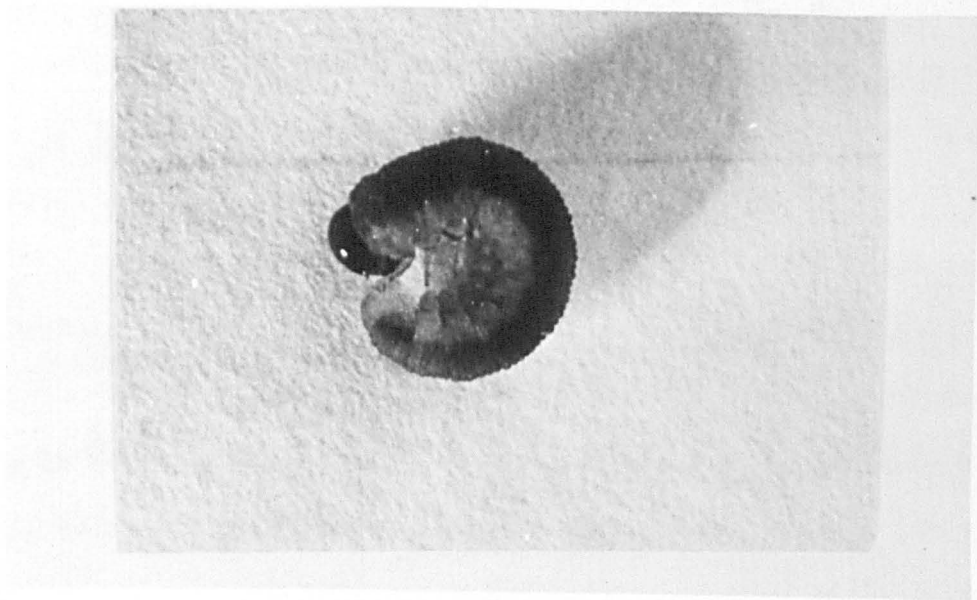
b. Sawfly larva found on rhododendron
leaf outdoors. x 10.

NEMATODES AS PESTS OF RHODODENDRONS

At the time when Fox-Wilson was compiling his list of animals attacking the rhododendron plant (1937), no nematodes were known to be pests. Since then several have been discovered in the soil around the plant roots, some feeding on the roots of azaleas and rhododendrons.

Ditylenchus sp.   (Pirone, D. and R. 1960)

Meloidogyne incognita   (Hunt 1957)

Rotylenchus robustus   (Tarjan 1953)

Trichodorus christiei   (Rohde and Jenkins 1957)

Tylenchorhynchus claytoni   (Sher. 1958)

Tylenchus sp.   (Pirone, D. and R. 1960)

Xiphenima americanum   (Christie 1952)

They are thought to cause stunt, general decline, chlorosis and die back (U.S.A. Ag. Ext. Bull. 1950). Although during this study I examined the soil around 'sick' rhododendron plants, no appreciable numbers of eelworms were seen. The few found at Willoughbridge were species of Xiphenima and Ditylenchus and I cannot be sure that they were parasitic on the plants.

Further studies into eelworms as pests of rhododendrons in Great Britain will have to be made.

In the U.S.A. the recommended control is dibromochloro-propane in water, 2 teaspoonsful for 100 square feet, sprayed on to the soil in autumn or spring whilst the temperature is above 65° F.

SLUG DAMAGE

In 1970 I received a report from a Mr. Jackson of Tatton Park, Cheshire, of severe damage to rhododendron plants by slugs (species unknown). The bushes were 4 - 5 feet tall and the silvery, slimy trails could be seen all the way up the stems. Damage to leaves and flowers was typical of slugs: indentations in the leaf margin, some holes and a scraping away of the lower epidermis in places.

The gardener went out after dark with a torch and found the slugs on both the leaves and flowers.

Rhododendron chaetomallum was the species most badly attacked and was in a bed surrounded by bedding plants, all of which were badly eaten by slugs.

The slugs were controlled by scattering Draza pellets containing methiocarb, which is a most efficient carbamate molluscicide. This is the only report of slug damage to rhododendrons, but the scraping of the epidermis could account for the similar "weevil" damage seen by Fox Wilson. It is quite likely that slugs also were present, as well as weevils.

KEY TO DAMAGE BY PESTS ON OUTDOOR RHODODENDRONS IN GREAT BRITAIN

1. Holes in lamina or leaf obviously bitten,
     sometimes petiole eaten 2

     No holes in lamina but leaf disfigured 6

2. Hole or holes in leaf margin regular, semicircular
     about 1 cm. in diameter (as Fig. a) .... Leaf Cutting Bee,
                                             Megachile sp.
     Holes in margin fairly regular, small (as Fig. b)   Nut leaf weevil,
                                     Strophosomus melanogrammus.

     Holes and damage to leaf irregular 3

3. Severe damage to margins, jagged dentations visible
     (as Fig. c) .... Cockchafer
                                         Melolontha melolontha

     Irregular damage with fairly smooth edges 4

4. Irregular damage, often severe especially on glaucous
     leaf. Sometimes leaves tied together (Fig. d) .... Caterpillars

     Damage less severe (as Fig. e) 5

     Irregular damage with small holes in lamina
     (as Fig. f) .... Serica brunnea

5. After dark in summer, small brown weevil found on
     leaves, about 6 - 8 mm. long .... Clay-coloured weevil,
                                     Otiorhynchus singularis

     After dark in summer, larger black weevil found
     about 1.3 cm. long .... Vine weevil,
                                     Otiorhynchus sulcatus

6. Leaf covered in black mould on upper surface 7

     No black mould 9

7. Small, oval, flat larvae on underside of leaf (Fig.),(Pl. 3).
     often small, white-winged insects on plant 8

     Not as above 10

8. On large-leaved rhododendron, probably
    Rhododendron Whitefly .... <u>Dialeurodes chittendeni</u>

    On small-leaved rhododendron or azalea,
    probably Azalea Whitefly .... <u>Aleurodes azaleae</u>

9. Brown "scuffiness" on underside of leaf,
    yellow spickling on topside .... Rhododendron bug,
                                                    <u>Stephanitis rhododendri</u>

    Not as above 10

10. Leaf green but with few yellow dots. Bud blast
    disease (Plate 8) often present. Long oval
    eggs on buds, insects on plants .... Rhododendron Leaf Hopper,
                                             <u>Graphocephala coccinea</u>

    Some spickling, some honeydew, greenfly present ..... <u>Aphis spp</u>.
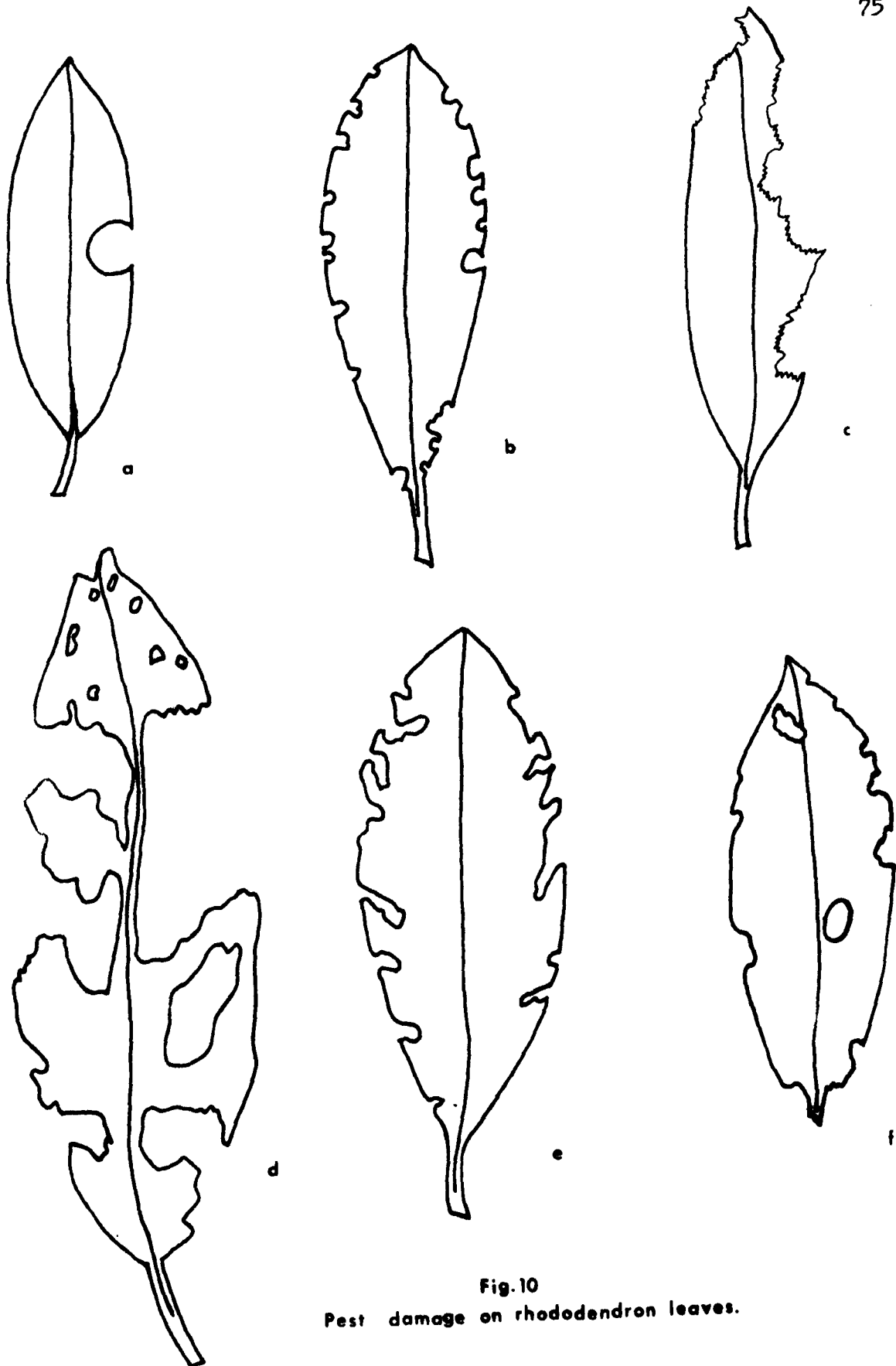
Fig. 10
Pest damage on rhododendron leaves.

Plate 24.

a.

Unidentified damage to leaves.

b.
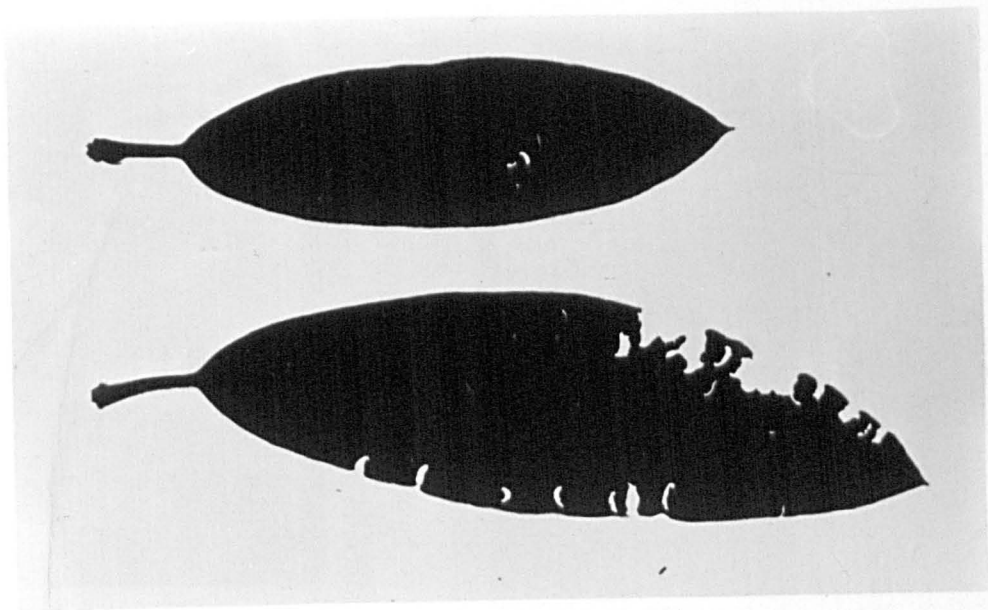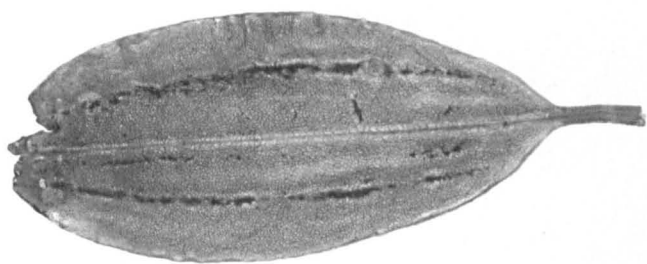
when these leaves are at a certain stage of development.   Further
investigation is being carried out.

(b)   Although I never saw any insect on these leaves when the
small, crescent-shaped holes were made, it is most likely that this
damage is caused by a biting insect pest, possibly a beetle or a
caterpillar.

Plate 25.

Natural Protection of the rhododendron bud.

This plate shows insects adhering to the outer,
very sticky scales of the unfolding rhododendron
leaf bud. The stickiness affords protection to
the inner, unfolding leaves.

PESTS OF RHODODENDRONS FOUND IN THE U.S.A.

AND OTHER COUNTRIES

Table vi.

The following are not considered to be pests in Great Britain, but are commonly found on rhododendrons in the U.S.A. or in the country mentioned.   Their description and control can be found in most agricultural or horticultural bulletins in the U.S.A., and references to some of these are made.

ARACHNIDA   Reference

Tetranychus bimaculatus	Harvey	
Paratetranychus ilicia	Mc G.	Davis and Libby (1961)
Brevipalpus inornatus	Banks	Pirone, D. and R. (1960)
Aculus rhododendronis	Keifer	Keifer (1959)
Tarsonemus palidus	Banks	Pirone, D. and R. (1960) Morishita and Jefferson (1957)

THYSANOPTERA

Thrips tabaci Lind.

Heliothrips haemorrhoidalis Bch.   } in U.S.A.

Found on seedlings of R. ponticum and greenhouse azaleas, R. indicum (Pirone, D. & R. 1960).   Controlled by spraying with malathion, lindane or DDT at regular intervals.

H. haemorrhoidalis also found in S. Australia (Steele 1935), on rhododendrons in greenhouses.

HEMIPTERA		Reference
Heteroptera		
Stephanitis pyroides. Scot	Azalea Lace Bug	Kerr (1959)
Homoptera		
Pseudococcus cuspidatae Rau	Taxus Mealybug	Rau, J. (1937) Kerr (1959)
Pseudococcus maritimus Ehrh.	Mealybug	Pirone, D. & R. (1960)
Pseudaonidia paeoniae Ckll.	Peony scale	Weigel and Baumhofer (1948) Pegazzano (1953)
Eriococcus azaleella Const. (syn. E. azalea)	Azalea Bark Scale	Schread (1954) Kerr (1959) Dozier (1937)
Aspidiotus pseudospinosus Vallot.	Rhod. scale	Davis and Libby (1961)
A. hederae Vallot.	Oleander scale	Davis and Libby (1961)
Masonaphis rhododendri		Pirone, D. & R. (1960)
Macrosiphum rhododendri Wilson		Westcott (1946)
Magicicada septendecim L.	"17-year locust", An interesting insect.	Cory and Knight (1937) Imms (1957) Turnipseed (1964).
Eutettix disciguttus Wlk.	Formosan	Takahashi, R. (1936)

LEPIDOPTERA

Sesia rhododendri Beut.	Rhod. Borer or Clearwing	Weigel and Baumhofer (1948)
(Larva burrows inside branches. Common pest in U.S.A.)		White (1933) Kerr (1959)
Gracillaria azaleella Brants.	Az. Leaf Miner	Schread (1961)
(Common in U.S.A., Japan, Holland, Belgium, New Zealand; less common in Great Britain)		Hodson (1927) Kerr (1959) Helson (1953)

LEPIDOPTERA (continued)

Pododsesia syringae Harr.   Lilac Borer   Schread (1954).
                                                    Weigel and Baumhofer
                                                    (1948).
Eucordylea huntella   Keifer, H.H. (1936)

COLEOPTERA

Oberea myops Hald.   Azalea Stem Borer

Popillia japonica Newm.   Japanese Beetle   Schread (1953)

Autoserica castanea Arrow.   Asiatic Garden Beetle
 (Very similar to Serica brunnea)

Corthylus punctatissimus Linn. Pitted Ambrosia Beetle
                 or Zimm

Pantomorus godmani Crotch.   Fuller's Rose Beetle

Rhabdopterus picipes Oliv.   Cranberry Rootworm

        Descriptions, life histories and controls of the above

beetles, all common in the U.S.A., can be seen in Pirone, Dodge and

Rickett (1960), in the U.S. Department of Agric. Misc. Pub. 626 (1948)

by Weigel and Baumhofer, and in most American books which refer to

pests of ornamental shrubs.   Felt (1924) describes the Pitted Ambrosia

Beetle.

Boloschesis spilota   Found in Japan   Kumazawa (1939)
(syn. Arthrochlamys spilota)   Ono, K. (1937)

Chlamisus laticollis   Granulated Leaf   Ohno (1962)
                                Beetle in Japan

DIPTERA

Giardoyia rhododendri Felt.   Rhod. Gall Midge   Felt, E.P. (1939)
    (Controlled in U.S.A. by lindane or malathion) Pirone, D. & R.
                                                     (1960)

HYMENOPTERA

Vespa crabro germana Christ.   Giant Hornet   Davis and Libby (1961)
                                                        Pirone, D. & R. and
                                                           others (1960)

Arge similis Voll.   Sawfly in Japan   Ii, N. (1934, a & b),
                                                        (in Japanese)

PART II

OTIORHYNCHUS SINGULARIS (L.)

a. NAME AND CLASSIFICATION

This insect belongs to the order Coleoptera and family Curculionidae, the weevils, the largest family in the animal kingdom. Sharp, in 1895, estimated 200,000 species of Curculionidae and now almost 70,000 species are described (Imms 1948). There is now a sub-family, Otiorrhynchinae.

Previously, until about 1800, most weevils were put in the one genus Curculio. The French entomologist Pierre Andre Latreille established the genus Brachyrhinus into which the Clay-coloured weevil was placed, having been described first by Linnaeus in 1767 as singularis, and then named picipes by Fabricius in 1776.

In 1824, Germar, apparently in ignorance of Latreille's previous work, named the genus Otiorhynchus in which he placed singularis and picipes and other species which were already referred to the genus Brachyrhinus.

Since that time Otiorhynchus and Brachyrhinus have been used synonymously, although Brachyrhinus has priority over the later name. In spite of this, however, in Europe the earlier name has never became accepted and Otiorrhynchus with one or two "r's" is generally used. In the U.S.A. both generic names are used, Brachyrhinus (with one "r") often being preferred. (Kerr 1959, Weigel and Baumhofer 1948). The original way of spelling both Otiorhynchus and Brachyrhinus was with one "r", so perhaps this should be adhered to, despite modern

practice in Europe.

Kloet and Hincks (1945) give the generic names thus:

Otiorrhynchus (Germar 1824) +

Brachyrrhinus (Latreille 1802)

+ meaning name invalid and/or research needed.

Dr. Zimmerman (1961) has applied for the suppression of Brachyrhinus in favour of the later name Otiorhynchus. Most Otiorhynchus species are European, and this is the name used in Europe; the Americans have only a few introduced species. This application is at present sub judice by the International Commission on Zoological Nomenclature.

Throughout the thesis, Otiorhynchus has been used to keep in line with common European practice. The name comes from the Greek otion (ear), and rhynchus (snout), and refers to the shape of the scrobes at the front of the rostrum.

The following synonyms are referred to by Hoffman (1950).

Otiorrhynchus (Dorymerus) singularis L.

Syst. Nat., 1767, ed. XII, Add., p. 1066.

- ? picipes FAB., (1) Mant. 1777, p.229.

- granulatus HERBST, Arch. Ins. - Gesch,   1784-85, p. 84.

- notatus BONDSD., Hist. nat. Curc. Suec., II, 1785, p. 39,

fig. 34.

- vastator MARSH., Ent. Brit., I, 1802, p.300.

- notatus STEPH., III Brit. Ent. Mandib., IV, 1831, p. 114.

    - Marquardti FALD., 1836 Bull. Pet., I, p. 179.

    - corniculatus REITT, Verh. nat. Ver. Brunn, LII, 1913, P. 16.

    - Cat. SAINT-CLAIRE-DEVILLE, p. 188.

Kloet and Hincks give O. or B. picipes as a synonym, but the names Otiorrhynchus singularis L., Brachyrrhinus singularis L., or Otiorhynchus singularis L., Brachyrhinus singularis L. are now those that are generally accepted.

According to Hoffman (1933), there is a Sub-genus of Otiorhynchus named Dorymerus Seidl., all species of which, including singularis, are covered with squamules or little rounded scales. Species are very similar in this group.
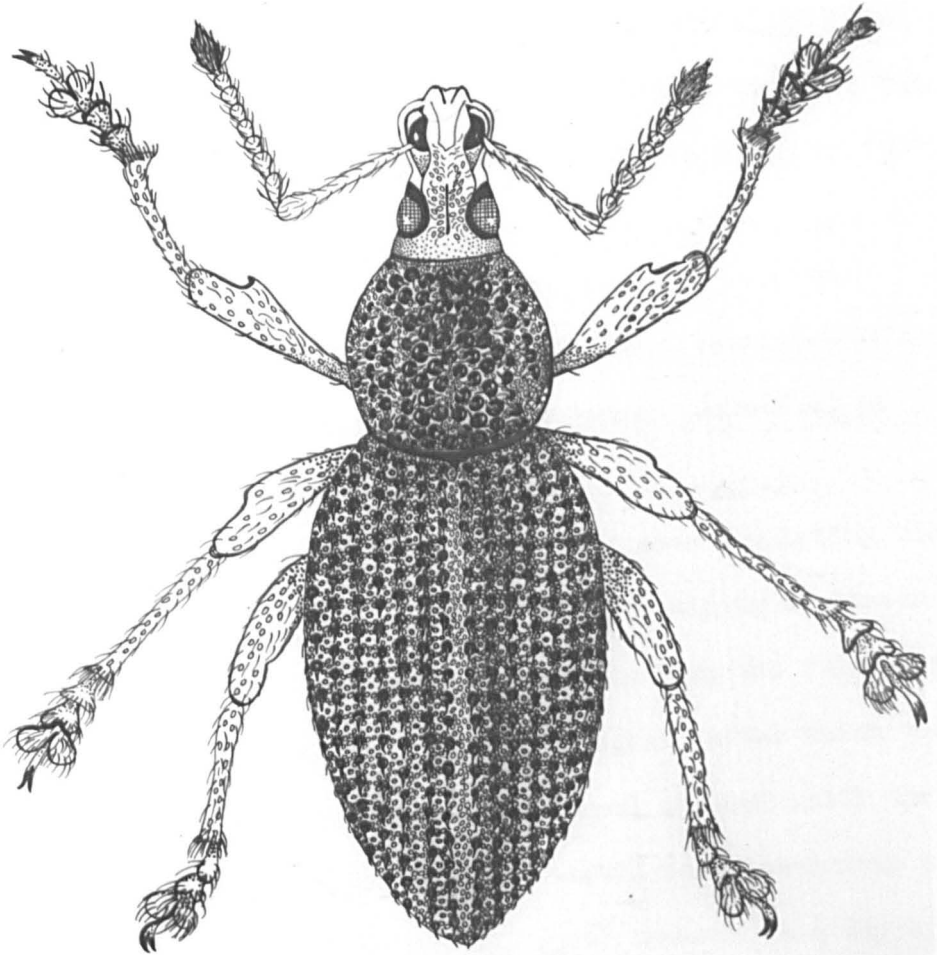
O. singularis. Dorsal view. × ~~20.~~ 16

Fig II.

LIFE HISTORY OF O. SINGULARIS

Whilst observing O. singularis in the laboratory it soon became apparent that there was not a straightforward annual generation, but that development of larvae depended upon temperature and that the adults could live longer than one year, laying a second batch of eggs during that summer also.

From my own observations I would agree with Willis (1964) about the timing of the different stages which I have tabulated below.

Eggs are laid from May until early October. Depending on temperature, these hatch within 30 - 40 days.

Larvae hatch from eggs from June onwards, some completing their development and pupating the same summer, others remaining as larvae in the soil over winter, about one foot deep, and pupating the following spring.

Pupae are found from early July until August, after which the adult weevil develops and remains within the pupal chamber until the following spring. This soft-bodied, adult weevil bears deciduous mandibles.

Adults emerge from soil in spring, April onwards, and lay eggs that summer. All are parthenogenetic. Most over winter as adults in soil and again lay eggs the following summer.

Although I found it impossible in laboratory conditions to follow a complete life cycle through from egg to second year adult, I have found all stages in the soil at the times which would substantiate

Willis's theory.   It is quite obvious that O. singularis does not
have a twelve-monthly cycle.   Eggs laid in early September, year 1,
for instance, would not become fully fed larvae and pupate until summer,
year 2; then, after overwintering in the pupal chamber, the adults
emerge to lay their eggs in, say, May, year 3.   Eggs laid in May
could develop more quickly through the larval stage, pupate and
become adult in year 1, but these adults would not emerge from the
pupal chamber and lay eggs until spring, year 2.

This difference in the length of development may account
for the great variation in size of adults within this species.

TABLE vii

LIFE CYCLE OF OTIORHYNCHUS SINGULARIS

Year	J	F	M	A	M	J	J	A	S	O	N	D	
1					E	E	E	E	E	E			Eggs late May-October
1							L	L	L	L	L	L	Some complete in one year and pupate, others overwinter.
2	L	L	L	L	L	L							
1 or 2							P	P					Pupate in July onwards
1 or 2								P_A	P_A	P_A	P_A	P_A	Adult in P. chamber over winter
2 or 3	P_A	P_A	P_A										
2 or 3				A	A	A	A	A	A	A	A	A	Adults emerge Spring onwards.
3 or 4	A	A	A	A									Some overwinter and hibernate.

88

club

funicle

scape

rostrum

eye

femur

prosternum

episternum

metasternum

depression on
1st. abdom. seg.

elytra

"dimple" on
5th. abdom. seg.
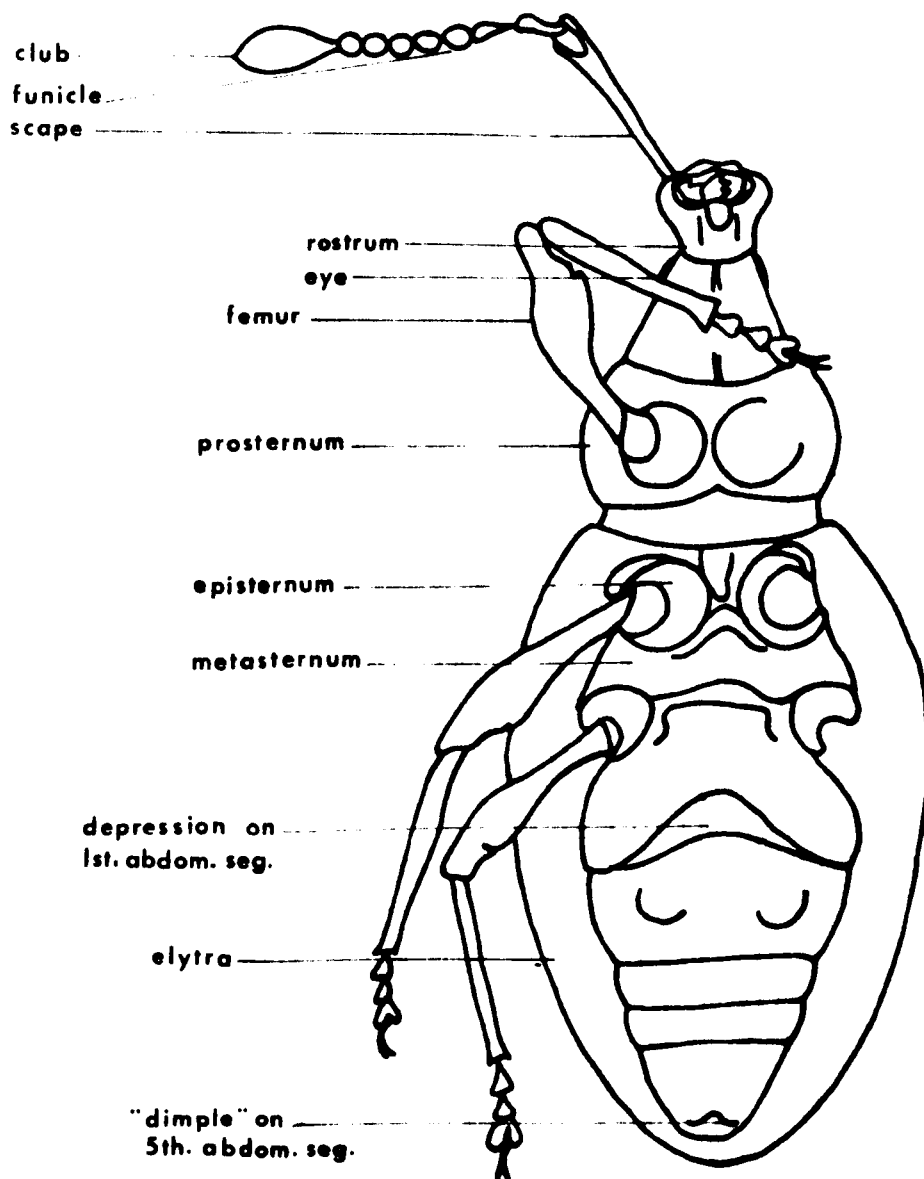
O.singularis.   Ventral view. ×16
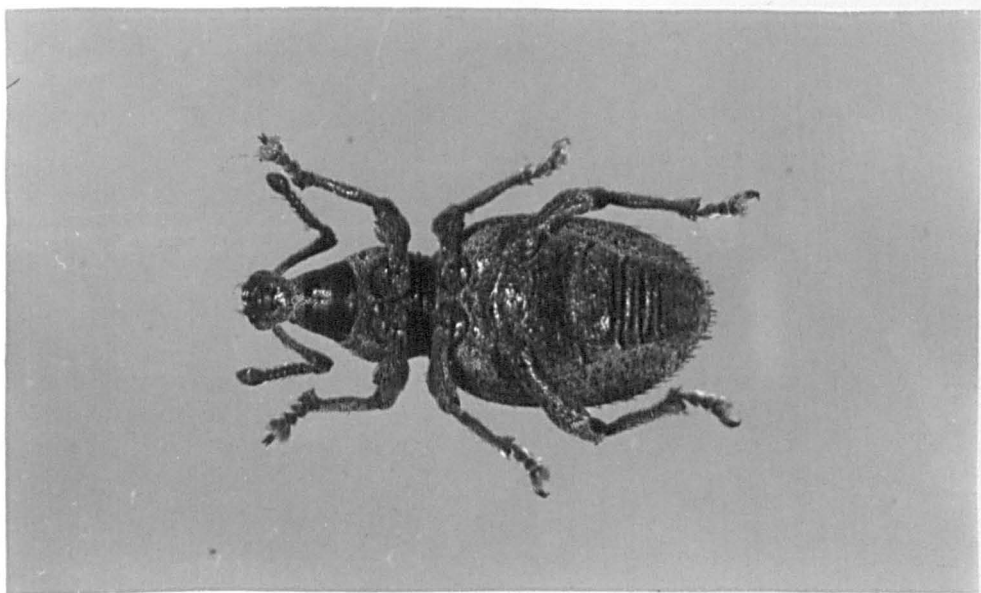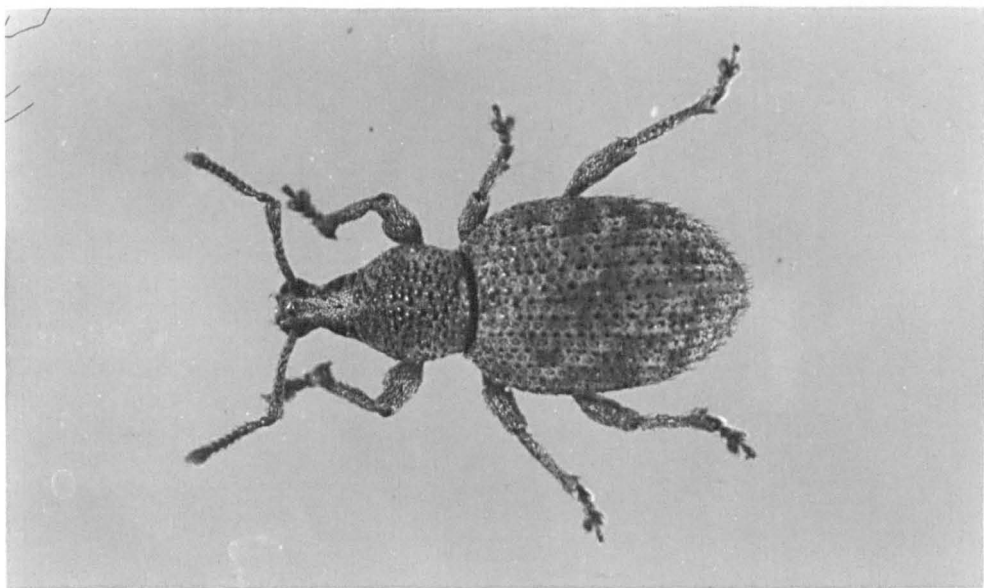
Fig.12

Plate 26.

Otiorhynchus singularis adult. ×9

a. Dorsal view.

b. Ventral view.

b. DESCRIPTION AND BIOLOGY

ADULT

As its English name implies, this weevil is clay-coloured at first sight, but on closer investigation can be seen to be dark brown, covered on the dorsal part of the body by golden-coloured, metallic-looking scales forming a mottled pattern of irregular, marbled patches. Soil often adheres to the elytra, camouflaging the insect still further. The under surface of the weevil is dark brown, shiny and scaleless.

The adult weevil is of an average length of 7.28 mm. in Staffordshire. I have found them from 6.10 mm. to 8.80 mm. Hoffman (1950) states 6 - 7 mm. Width at the broadest part of the abdomen is 2.95 mm.

The convex, oval elytra are fused and the insect is there-fore flightless. On the elytral instertices are yellow hairs which lie in a horizontal position on the side of raised granules, and point backwards. The granules are not umblicated and Hoffman (1932) uses this feature to distinguish between this species and D. veterator Uytten.

On the dorsal surface of the thorax, which is rounded, about 2 mm. long and the same in width, the hairs arise from convex shiny granules, and besides lying closer to the surface than those on the elytra,they point towards the centre of the thorax rather than towards the posterior end of the animal.

The head of O. singularis is on average 2.1 mm. long and 1.2 mm. at the widest part. It is at an angle of about 35° to the thorax, pointing downwards.

The two scrobes are deep and almost continuous with the eyes. They are shallower behind the antennae and the pterigium at the edge of the scrobe is not so pronounced as in many Otiorrhynchus species.

The two black compound eyes are fairly prominent and round, borne on each side of the narrowing of frons and vertex to form the rostrum.

When newly emerged, the weevil has a pair of deciduous mandibles (Willis 1964) which are discarded almost immediately. Normal mouthparts are then present.

The antennae are geniculate and clubbed, the scape being inserted in the scrobe. Average length of the antennae is 3.6 mm. All parts are densely covered with light brown hairs. There is a pedicel between the scape and funicle, the latter having 6 segments. The club is not as tapered as in other common Otiorrhynchus species and averages 0.5 mm. in length.

In the first segment of the abdomen there is a central shallow depression, in the second, two slight depressions on each side. There is a slight dimple or small depression on the anal segment. (Fig. 12).

A pair of strong legs arise from each of the prosternum, episternum and the metasternum. The coxa is round, the femur claviform

Antenna.

|⊢——————————————⊣|
1 mm.

O. singularis
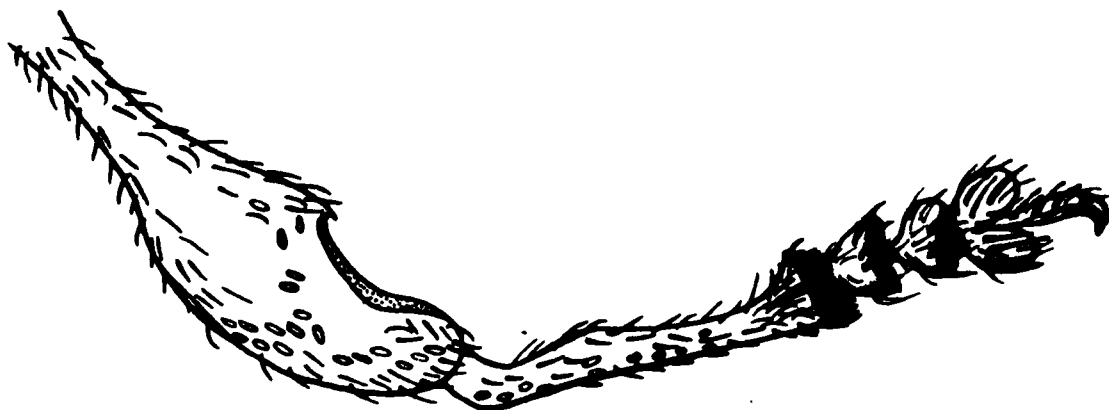
Leg.

|⊢——————————————⊣|
1 mm.

Fig. 13

Plate 27.

.

.

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Eggs of O. singularis.

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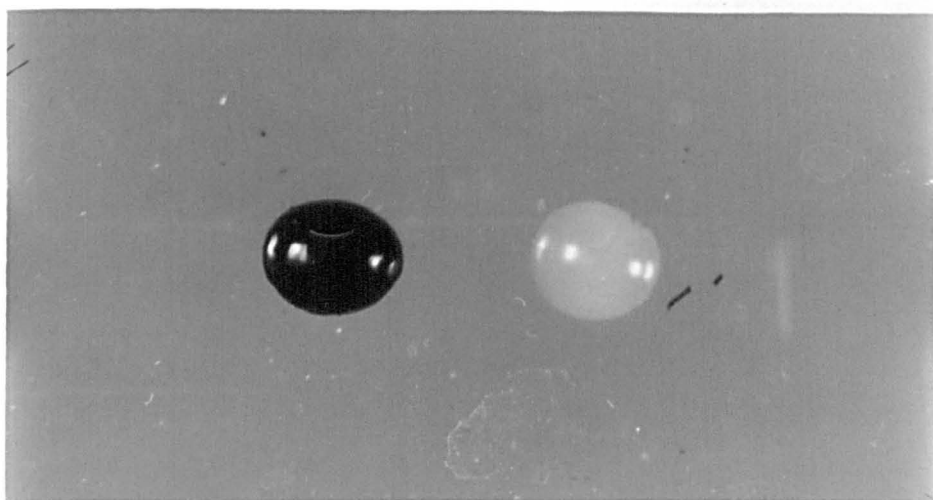
and toothed; the tibia is narrow, and has a fringe of stiff hairs at the base. Both these parts are covered in brown hairs and some light coloured scales. The claws are large, free and equal, growing between a pair of mucronate pulvilli.

The elytra are visible ventrally on each side of the abdomen.

EGGS

The eggs have been described by van Emden (1950) and Willis (1964). The following are my own observations:-

The eggs are ovate, 0.75 mm. - 0.8 mm. long and 0.6 mm. wide. When laid they are white, changing in 2 - 3 days to brown, then shiny-black. Some are not viable and do not change colour.

They are laid in the top soil, and one weevil may lay up to 100 or more eggs. In the laboratory they are usually laid between the lid of the petri-dish and outside of the base of the dish, or in the right-angled bend in dish.

Numbers laid in the laboratory over 20 weeks in 1963 varied greatly (see following page).

TABLE viii

Weevil No.	Eggs laid	Weevil No.	Eggs laid	Weevil No.	Eggs laid
1	41	11	22	21	40
2	3	12	44	22	0
3	12	13	34	23	118
4	30	14	81	24	0
5	1	15	17	25	44
6	31	16	60	26	0
7	27	17	45	27	0
8	55	18	70	28	33
9	12	19	5	29	54
10	91	20	17	30	29

The eggs were laid in different batches, often over several weeks, e.g:-

Weevil No.	Date:week ending	No. of eggs laid	Weevil No.	Date:week ending	No. of eggs laid
15	31. 5. 63	1	23	14. 6. 63	34
	7. 6. 63	3		19. 7. 63	30
	14. 6. 63	4		26. 7. 63	18
	21. 6. 63	2		1. 8. 63	3
	28. 6. 63	5		8. 8. 63	4
	5. 7. 63	1		15. 8. 63	29
	5. 9. 63	1			

Sometimes, however, all were laid in one batch, overnight, e.g:-

Weevil No. 13   24. 5. 63   34 eggs

In the soil I have found only small numbers of two or three close together, and would presume that there is no "nest" or one place for egg laying, but that they are laid at random.

I have never seen eggs deposited on the rhododendron plant, but have seen them on fallen leaves and flowers in the soil litter.

Outside, the first eggs are laid about the end of May and egg laying continues until late September - October but, as future experiments will show, egg laying is very dependent upon the temperature at which the adult is living.

In the laboratory, it appears that the humidity surrounding the eggs is critical. In a low relative humidity the eggs dry out and do not hatch, whilst if saturated they are easily attacked by a fungus and remain white or brown, not changing to shiny-black, nor hatching.

It is difficult to quote an "average" of numbers of eggs laid because the individual numbers varied so greatly, as did the time at which they were laid and the numbers at each laying. Willis quotes 41 eggs per weevil. The "average" in my own experiments in 1963 was 33.5.

The female weevils are not fertilised before egg laying and many of those listed above laid eggs in the following spring also:

TABLE ix

Weevil No.	Number of eggs laid 1964	Eggs laid in 1963
6	18	(31)
7	34	(27)
13	19	(34)
15	49	(17)
20	18	(17)
21	1	(40)
22	16	(0)
27	14	(0)

The other weevils
were not alive   Av. 21.0 eggs   Av. 33.5 eggs
in 1964.

Although on average more eggs were laid in the first

(1963) than the second year (1964), it is obvious that 5 of the 8

weevils remaining alive in 1964 laid more eggs than in 1963.

This agrees with Willis's observations on O. sulcatus where

more eggs are laid by the second-year adult than the newly-emerged

adult.

The number of eggs laid seems to depend on the type of

leaf eaten.   Willis states that from 77 - 90 eggs are laid per weevil

fed on strawberry.   Observations in the laboratory at Keele showed

that weevils fed on Primula, Rose Bay Willow Herb and Raspberry laid

more eggs than those fed on Rhododendron, but precise, comparative

figures are not available for all plants.

Below are some figures for eggs laid in 1965 from May 18th

until July 22nd, by weevils feeding on the named plants.

TABLE x	No. of weevils	No. of eggs	Average No. per weevil
Rhododendron	11	58	5.3
Raspberry	18	132	7.3
R.B.W. Herb	17	103	6.0
Nettle	2	0	0.0
Holly	3	12	4.0

Incubation period

This varied between 27 and 40 days, depending on the date laid and the temperature. Those laid at the end of May had the shortest incubation period. Eggs laid at the end of the season, October, often died without hatching.

Experiments dealing with egg laying follow in a later part of this chapter (p.168).

LARVA

The larvae are white, small, legless with a light-brown head. Length from 1 mm. to 4 mm. with head width about 0.4 to 1.5 mm. Willis (1965) states that, as there are two distinct peaks for headwidth, probably some larvae complete their growth in summer, others in spring. There are six larvae instars and pupation takes place when the headwidth exceeds 1.3 mm.

Larvae, in the soil, feed on the roots of trees, bushes, hedgerow plants and some soft fruit crops. They do not appear to cause any serious damage (Hill 1952) and I have never seen them damaging rhododendron plants to any extent. (The larva of O. sulcatus appears to cause more damage to plant roots than does O. singularis).

From the point of view of the horticulturist, the adult weevils are more easily separated and identified than the larvae and also cause most damage to rhododendrons, but a method of identifying the larvae is set out below.

In the laboratory the larvae will live, moult and grow on damp filter paper if supplied with a little soil and macerated roots.

IDENTIFICATION OF O. SINGULARIS LARVAE

Much work has been carried out in the past by Roberts (1926), Barrett (1930), Keifer (1932), Fidler (1936), Anderson (1942), van Emden (1950 and 1952), Fowler (1963) and Willis (1964) into the chaetotaxy and identification of Otiorhynchid larvae. Willis gives detailed descriptions and a key. Extracts from his work and that of Fowler are

Fig. 14

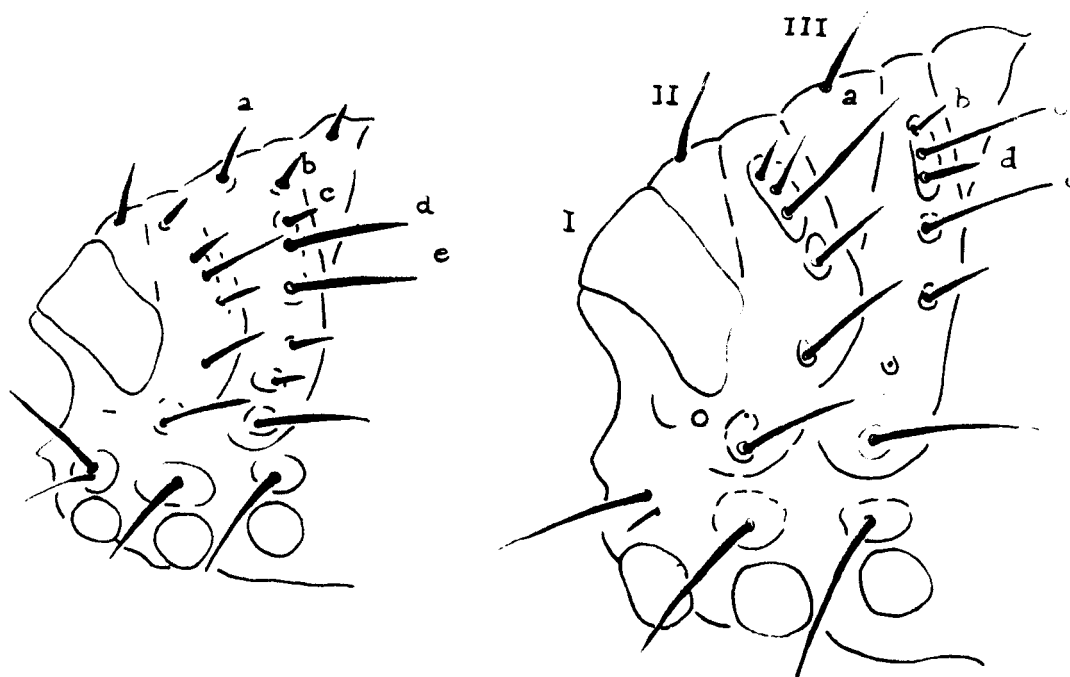O. singularis.   O. sulcatus.

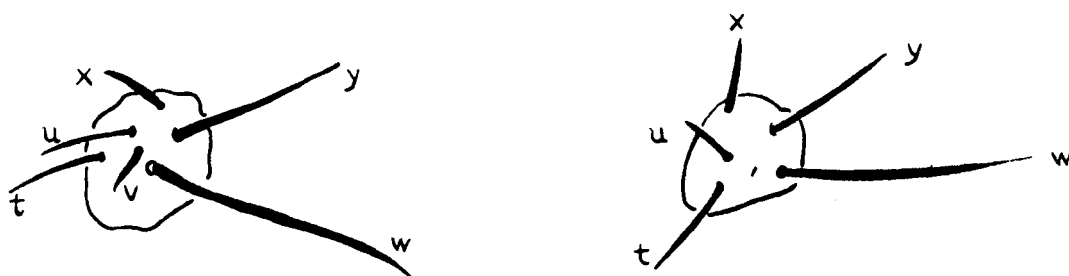Lateral view of thorax (after Willis).

Fig. 15

O. singularis.   O. sulcatus.

1st. pedal lobe (after Willis).

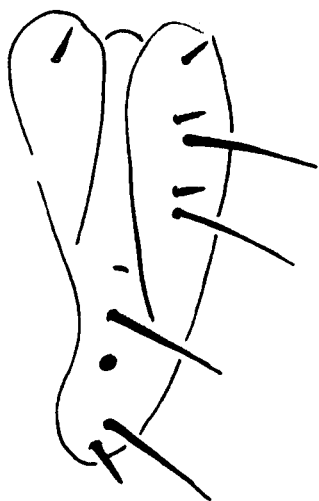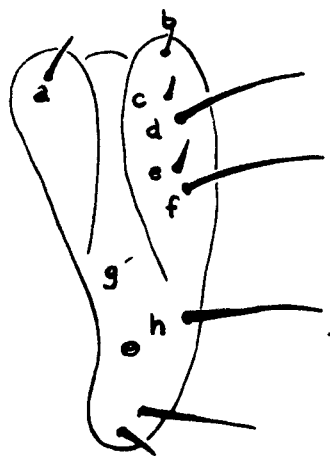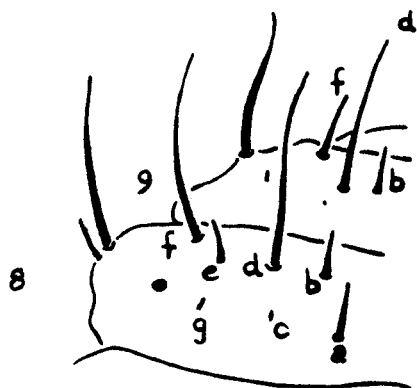**Fig.16**

O. singularis   O. sulcatus

Abdominal segment 5 (after Willis)
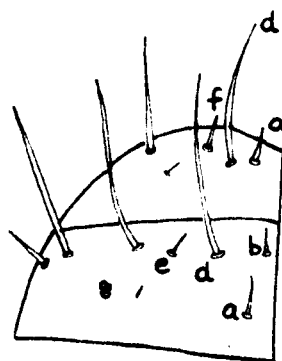
(after Willis)   (after Fowler)

O. singularis.

Abdominal segments 8 & 9.

Fig.17

set out below to separate the particular features of the larvae of

O. singularis from those of O. sulcatus, both of which species are

found on rhododendrons.

Head   The chaetotaxy of the head is similar to that in all

Otiorhynchus species.

Ocellar spots are faint and disappear as the larva develops

(in O. sulcatus they are distinctly dark and noticeable).

Thorax   On the postnotum of the metathorax the setae b, c, d, e

(van Emden 1952) are arranged by length, ıı‖ (whilst

ı‖ı in O. sulcatus). In both these species, the

setae of the mesothorax are arranged ıı‖ı (Fig.14).

The seta 'v' on the Pedal lobes is prominent in O. singularis

(about the same as 'x'), but is inconspicuous in other

species (Fig.15).

Abdomen   Here the chaetotaxy differs slightly from other Otiorhynchus

species.

1 - 5   In O. singularis segments 1 - 5 are similar, post tergal

setae b, c, d, e, f being ıı‖ı‖ (in O. sulcatus only

segments 1 - 4 are similar; in segment 5 the posterior

shift of seta 'h' is very conspicuous). (Fig.16).

6 - 8   In segments 6 - 8 seta 'h' is absent and 'g' very small.

Segment 8, seta 'c' is absent (very small in O. sulcatus).

9   There is some controversy about the setal pattern on

segment 9. Fowler states that setae a, d, f form a

triangle in O. sulcatus and more or less a straight line

Plate 28.

Pupa of O. singularis.
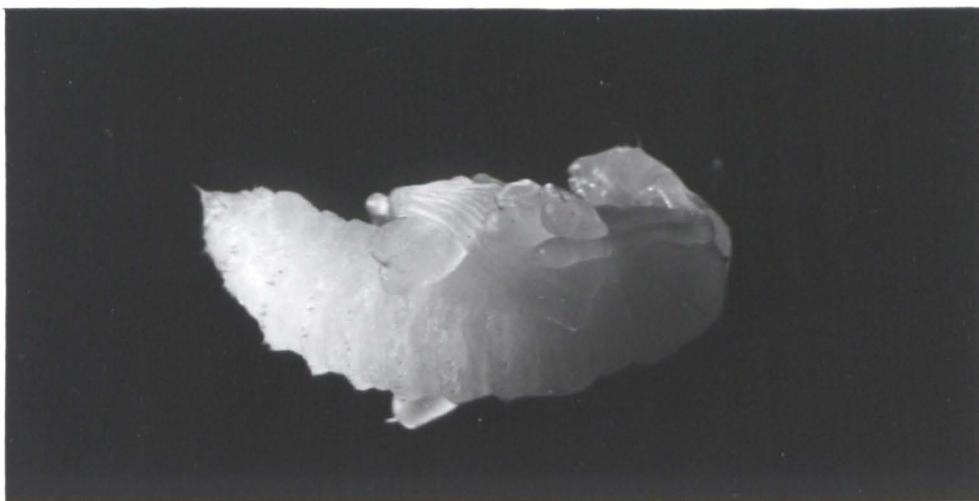
in O. singularis (Fig.17).   Willis writes that seta 'a'
is normally absent in O. singularis and the three setae
mentioned by Fowler should be more correctly b, d and f.
(Fig.17).   When,rarely,'a' is present, it is in such a
position as to form a triangle with 'd' and 'f' and is
therefore similar to O. sulcatus.

I would disregard this last arrangement on segment
nine as not reliable enough to be used in the identification
of O. singularis larvae, rather relying on the differences
of chaetotaxy of the metathorax and the pedal lobes, and
on the faintness of the ocelli.

PUPA

The pupa is soft and white, later turning brown.
They were found within a round hole or 'cell' in the soil during
August and up to September 9th, usually about 6 - 12 inches deep.
Length 4.5 mm.

On exposure to the air and to laboratory conditions,
the pupae soon dried up and died.   In no case did they complete their
development into adult weevils.

The form of the pupa can be seen in the accompany-
ing photographs (Plate 28).   Many of the appendages, including legs,
antennae and elytra are clearly defined.

Jorgensen has used the placing and length of the
setae on the last abdominal segment in separating some of the pupae
of Otiorhynchus species.

c.   COMPARISON OF O. SINGULARIS WITH OTHER OTIORHYNCHUS

SPECIES FOUND IN GREAT BRITAIN

In the British Museum (Natural History) collection, the following nineteen species of British Otiorhynchus species are represented:

clavipes	fuscipes	auropunctatus
morio	atroapterus	arcticus
nodosus	raucus	rugostriatus
ligneus	scaber	singularis
sulcatus	ligustici	rugifrons
ovatus	desertus	niger
portcatus		

Two of these (morio and niger) are represented by only one specimen and are doubtful British species.

Joy (1931), in his key to British weevils, omits fuscipes and nodosus and mentions raucus and ligustici as being rare and very rare respectively.

Willis (1964) mentions thirteen species amongst which are auropunctatus, portcatus and dubius found in Ireland.

Other species such as articus, nodosus and scaber are found locally in Scotland only.

For the purpose of identifying the major horticultural Otiorhynchid pests in Great Britain, I have selected only the six most commonly found throughout the country and these correspond to

O. singularis

O. sulcatus

O. clavipes

x9   Fig.18

104

O. ovatus

O. rugifrons   Fig. 19

x 9
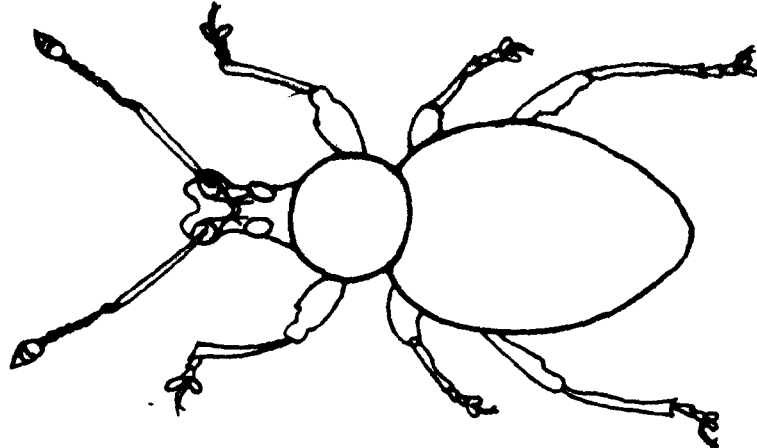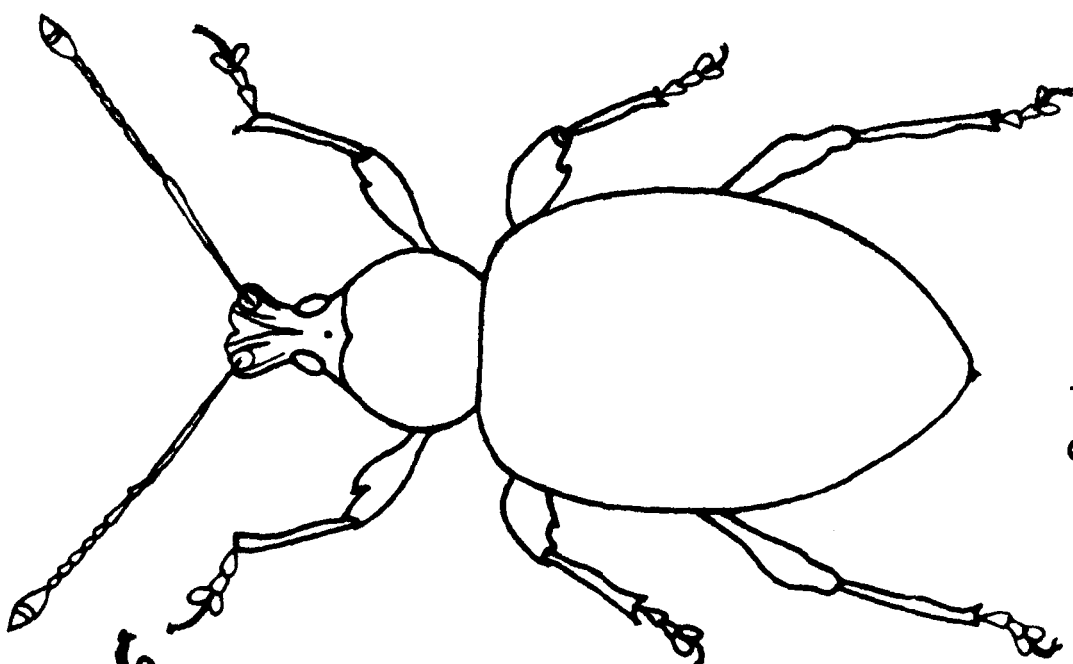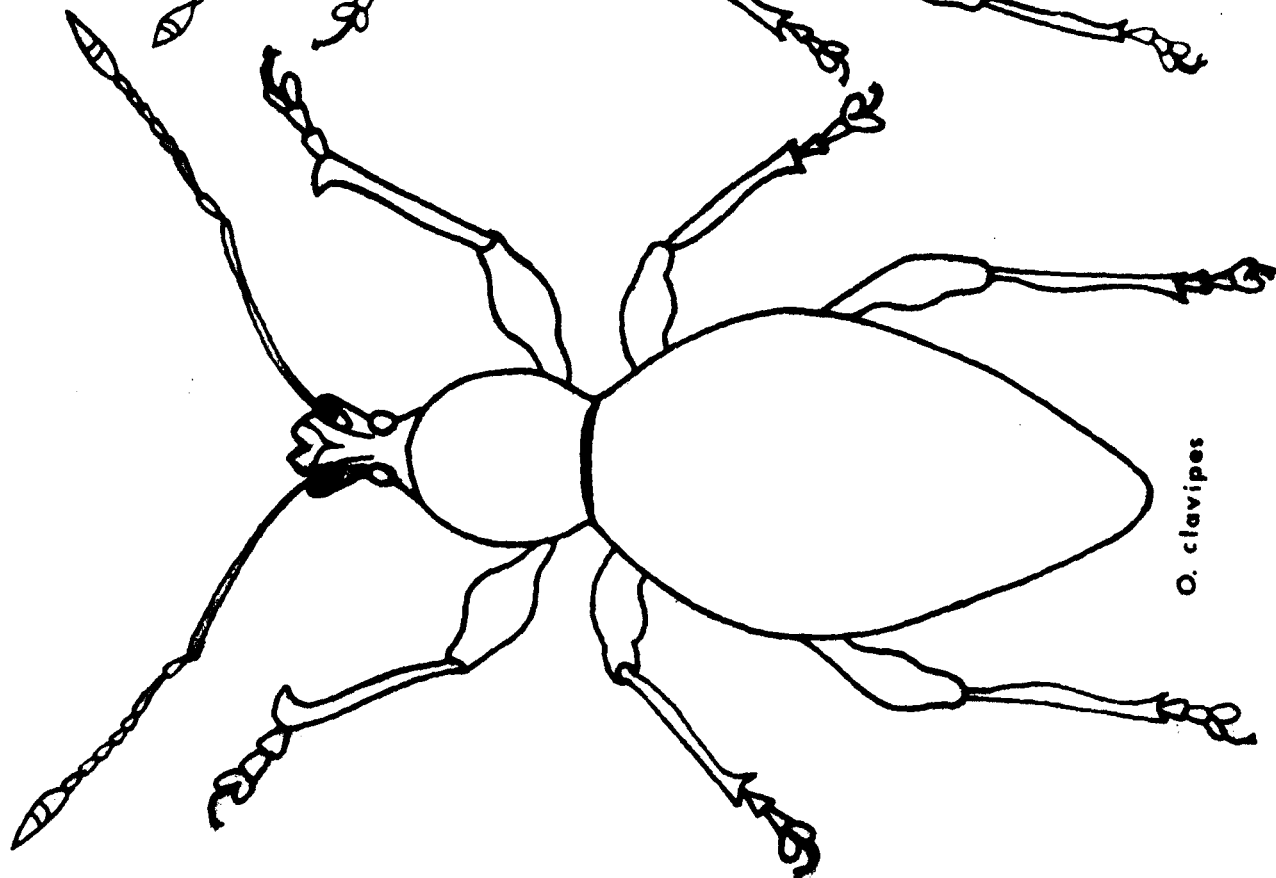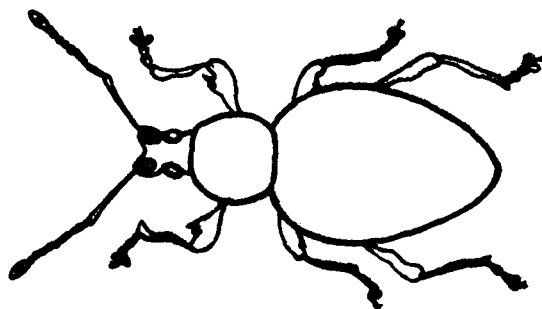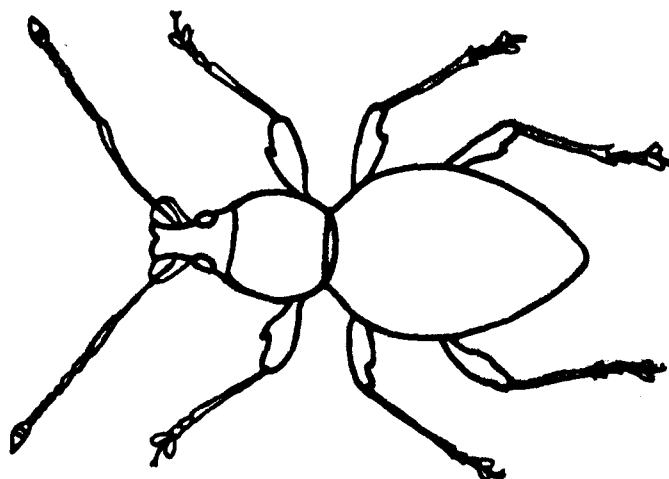
O. rugostriatus
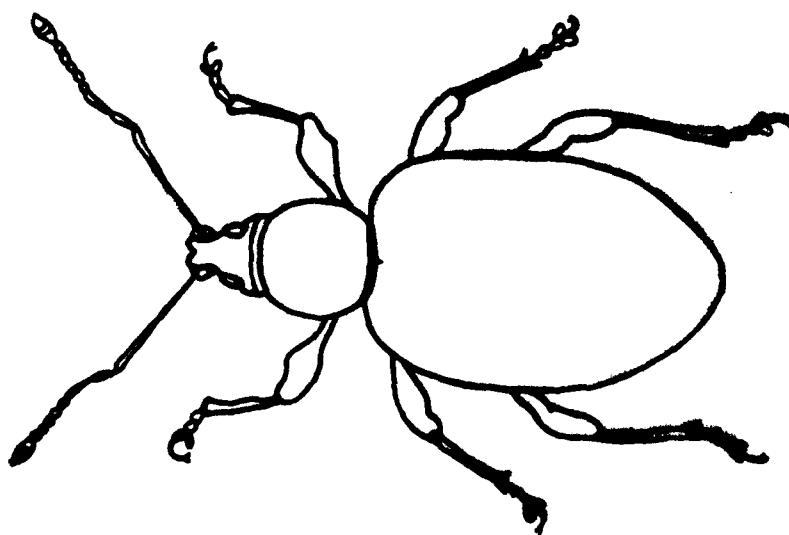
those mentioned in the M.A.F.F. Advisory Leaflet No. 57 (1963).

The following species will be compared:

		Synonym
O. singularis (L.)	Clay coloured	(O. picipes F.)
O. sulcatus (F.)	Vine weevil	----
O. clavipes (Bonsd.)	Red-legged weevil	(O. tenebricosus Oliver)
O. ovatus (L.)	Strawberry root weevil	----
O. rugifrons (Gyll.)	Strawberry root weevil	----
O. rugostriatus (Goeze.)	Strawberry root weevil	(O. scabrosus) Marcham.

Although only these six are named in the table and key which follow, the same characters can be used in the identification of all the Otiorhynchus species.

CHARACTERS USED IN SEPARATING OTIORHYNCHUS SPECIES

1. Size.

Although there is a great difference in the average length of these species, within each species there is such a range of sizes that this character alone is insufficient for identification. The largest mentioned is O. clavipes, up to 12.8 mm. long, and in contrast O. ovatus can be as short as 4.2 mm.

2. Colour.

This again is an unreliable character in some cases, for although some weevils are always brown (O. singularis) and others black (O. sulcatus), there are some (O. ovatus) which are such a dark

red that at times they appear black and are also brown when immature.

3. Shape.

All have the long rostrum and elbowed antennae, but the shapes of the heads and fused elytra vary considerably (Fig.18). (Fig 19)

4. Dorsal surface.

The weevils may be covered in scales (O. singularis) or not. They may have granules on the thorax and elytra, sometimes umbilicated, often hairy. Others (O. clavipes) have no granules and the shiny surface is punctured. The elytra may have definite striations or not. Each weevil differs slightly in its surfaces of the thorax and elytra.

5. Angle of head.

Although this may vary very slightly within a species, the angle of the head to the thorax varies enough between some species to be significant. O. ovatus has a short head bent downwards. O. singularis and O. rugifrons have the most horizontal heads in this group.

6. Indentations and markings on frons.

Perhaps one of the most reliable characters for identification and one overlooked by some other workers in this field. Between the scrobes and the eyes, above the nasal plate, each species has different markings (Figs. 20 - 25). These can mostly be seen with a hand lens and take the form of dots or ridges or depressions.
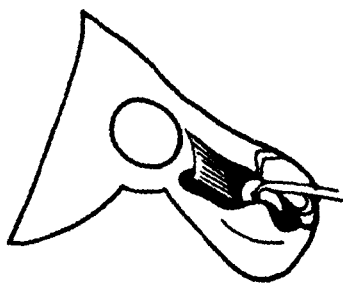
a
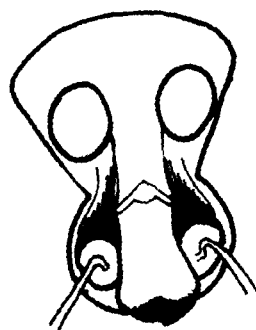
Fig. 20

b

O. singularis

a

Fig. 21

b

O. sulcatus

a — Fig. 22 — b

O. rugifrons

a — Fig. 23 — b
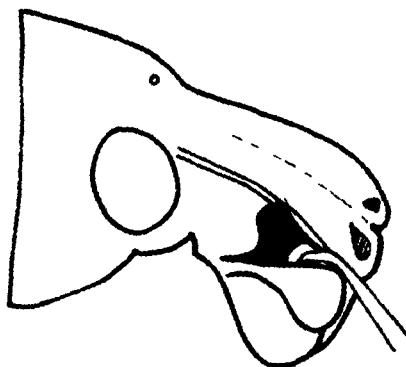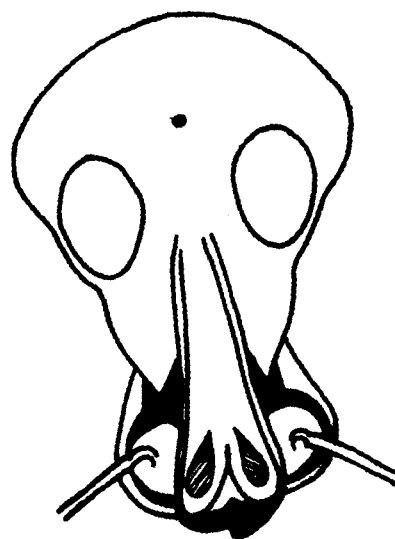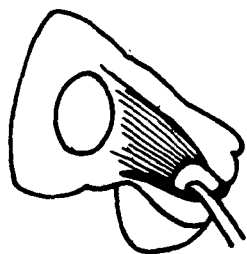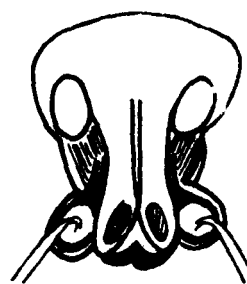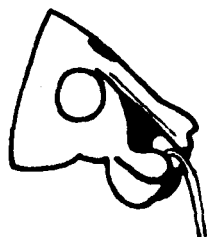
O. ovatus
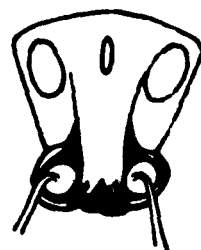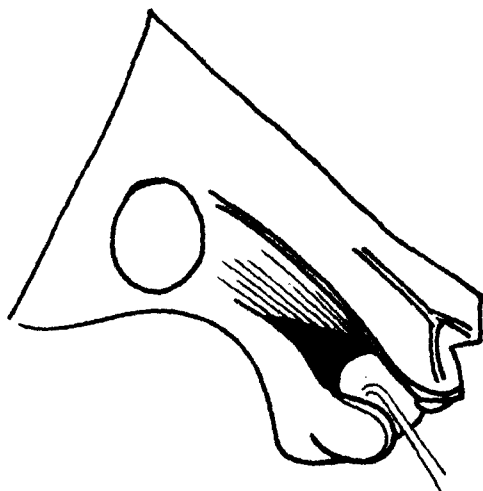
a
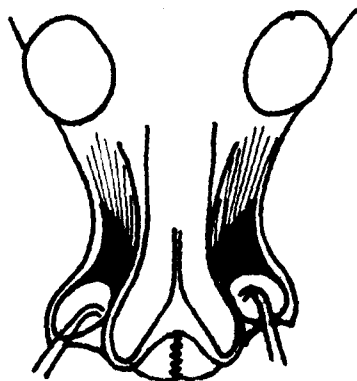
b

Fig. 24

O. clavipes

a

Fig 25

b

O. rugostriatus

Plate 29.
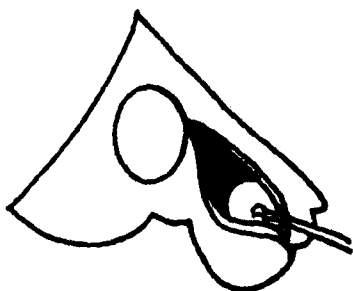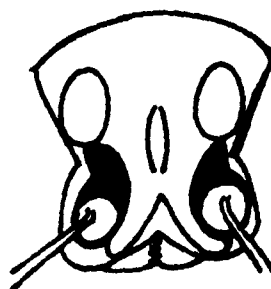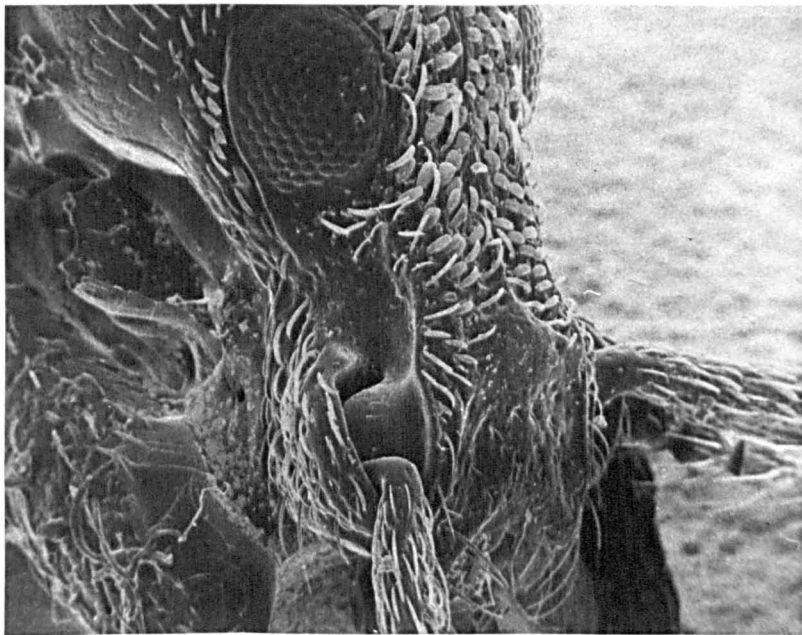
a.
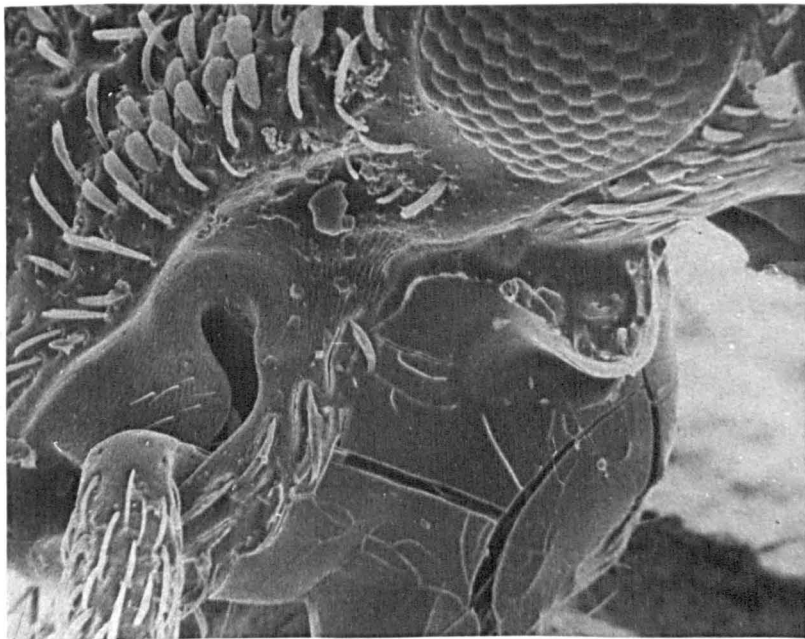
b.

Photographs taken by the electronic microscope to show
the shape of the scrobe of <u>Otiorhynchus singularis</u> and
the insertion of the antennae.

  a. Left-hand scrobe x 55

  b. Right-hand scrobe x 100

7. Eyes.

Prominence and colour differ amongst the species, but probably the distance from the eye to the scrobe is more significant. This is also shown in the table.

8. Scrobes.

These are significant in their size, shape (whether open or closed), position on the rostrum and also in the pterigium or lip around the edge of the scrobe.   In O. singularis the pterigium is not pronounced, but it is very noticeable in O. rugifrons.   The scrobes are deeper in O. singularis and O. clavipes than in O. sulcatus and O. ovatus.

9. Antennae (Fig. 26).

The clubs vary in length and shape between the species, also to a lesser extent in their colour and hairiness.

The lengths of scape, pedicel and funicle vary between species, as do the shape of the segments in the funicle.   O. rugifrons appears to have a short stalk to each rounded funicle segment, most of the others are rounded as in O. singularis.   In O. clavipes the first segment of the funicle is elongated more than in other species.

10. Legs.

All have free claws, but the indentations on the femur and the straightness of the tibia on the prothoracic legs are useful characteristics for identification: e.g. O. ovatus has a bipartite femoral tooth, O. clavipes has no sharply defined tooth.
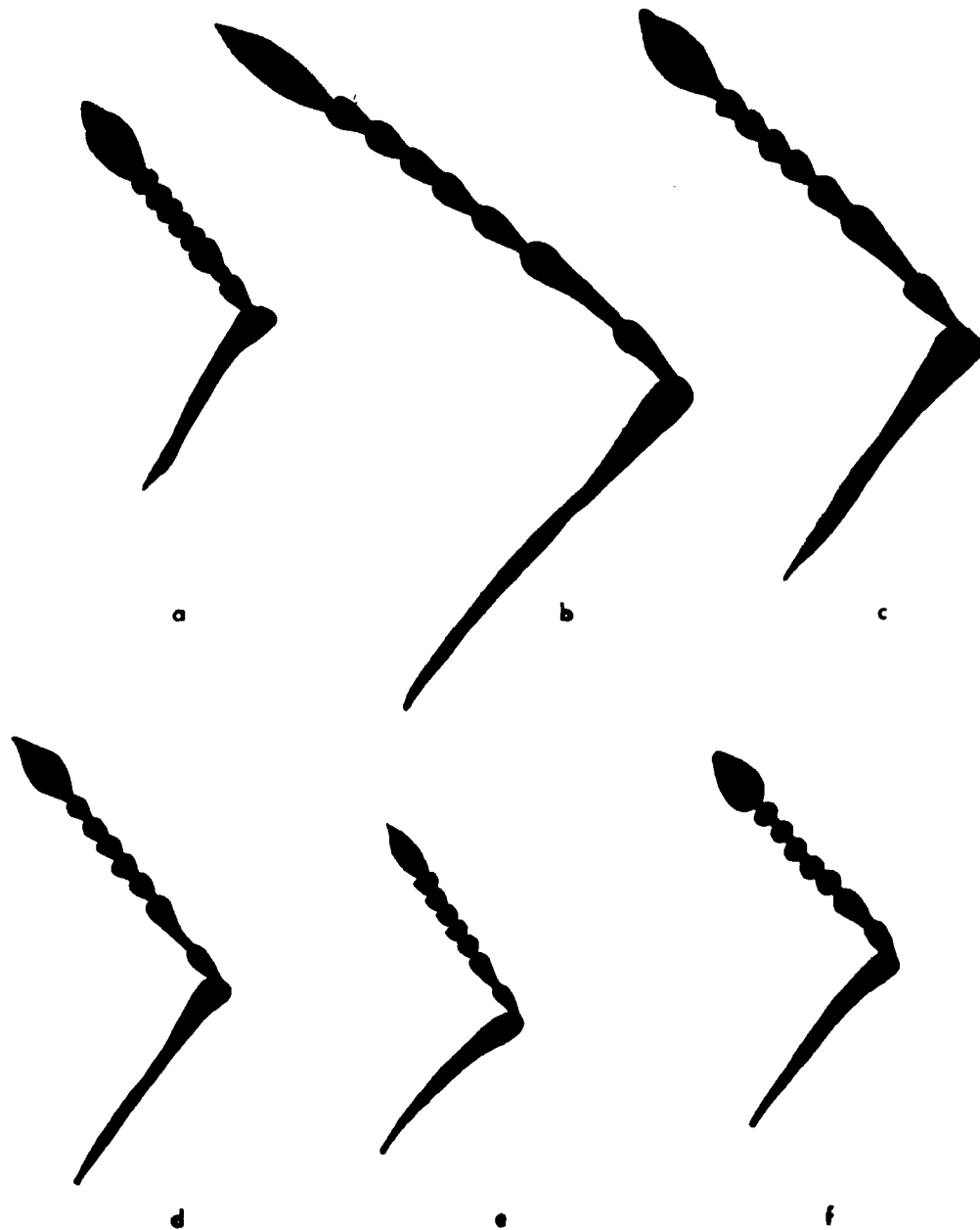
Antennae of Otiorhynchus species: x 20

a.   singularis   d.   rugostriatus

b.   clavipes   e.   ovatus

c.   sulcatus   f.   rugifrons

Fig. 26

113

Fig. 27

11. <u>Depressions in abdomen.</u>

On the ventral side of <u>O. singularis</u>, the last segment is dimpled.   Other species show no such depression.

TABLE xi

COMPARISON OF SOME OTIORHYNCHUS SPECIES

	O. singularis	O. sulcatus	O. clavipes	O. ovatus	O. rugifrons	O. rugostriatus
Average length	7.70	10.17	12.30	4.74	5.66	7.40
Longest in mm.	8.90	11.60	12.80	5.50	6.40	8.00
Shortest in mm.	6.20	9.40	12.00	4.20	4.80	6.90
Colour:	Brown	Black	Shiny, dark red	Very dark red (black)	Black	Lt.brown to black
Surface of thorax	Granulated, hairy.	Granulated, hairy.	No.grans. Surface shiny and pitted on both thorax and elytra.	Ridges in centre. Grans. at sides with hairs.	Round grans. merging in centre; hairy.	V.round granules umbilicated.
Surface of elytra	Striations. Golden scales on all dorsal surface.	Wide striations. Tufts of silvery hairs.		V.shallow striations. Hairs fine & short.	Shallow striations. Hairs in rows.	Wide,shallow striations.Flattened granules with hairs.
Prothoracic leg femur:	Scales. Hairy. V. small tooth.	Black. One deep dentation.	Red. No tooth.	Brown-red. V.pronounced double tooth.	Brown. Small,pointed tooth.	Brown. No tooth.
tibia:	Straight.	Curved slightly.	Straight.	Curved slightly.	Straight.	Straight.
Markings on frons	∧ between scrobes.	° central,above eyes.	A on clypeus.	() between eyes.	Central ridge.	() central.
Angle of head to abdomen	30 - 35°	30° Thorax more angled than other spp.	40°	50°	30°	40°
EYES: Shape:	Round.	Oval.	Round.	Round.	Oval.	Round.
Prominence:	Fairly.	Not very.	Prominent.	Prominent.	Not very.	Medium.
Colour:	Black and gold.	Black.	Red-brown.	Gold and black.	Light brown.	Gold and black.
Distance from scrobe:	Almost touching, 0.1 mm.	0.4 mm.	Distant, 0.5 mm.	0.4 mm.	0.1 mm. from shallow end.	V.near, 0.1 mm. or less
SCROBES: Shape:	Open, large.	Point not towards eye.	Pointed towards eye.	Oval, short.	Open.	Open.
Depth:	Very deep.	Deep.	Deep at front,shallow nr.eye.	Deep at front.	Very deep.	Fairly deep.
Pteridium:	Hardly present.	Fairly pronounced at lower edge.	Very pronounced.	Pronounced below.	Very pronounced.	Pronounced.
ANTENNAE: Hairs:	Light, coarse.	Fairly coarse,light.	Fine, light.	Fine, light.	Light brown.	Fine,long,light.
Club:	Short, rounded,slightly tapered.	Tapered.	V.long and slender.	Wide, tapered,	Short, wide.	Long,wide,tapered.
Pedicel:	Short.	Long.	Long.	Short.	Medium.	Fairly long.
Funicle:	Rounded segments.	Rounded segments with short stalks.	Segs. not very round, long.	Stalk between segments.	Segments rounded.	Segs. rounded with short stalks.
Depressions in abdominal segment.	"Dimple" in last segment. Depression in 1st segment.	nil	nil	nil	nil	nil

Plate 30.

Otiorhynchus clavipes.

Otiorhynchus rugostriatus.

Otiorhynchus sulcatus.

M/M 1   2   3

M/M 1   2   3

M/M 1   2   3
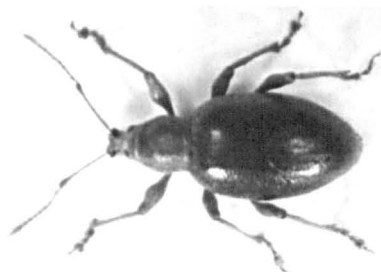
Plate 31.

Otiorhynchus singularis.

Otiorhynchus rugifrons.

Otiorhynchus ovatus.
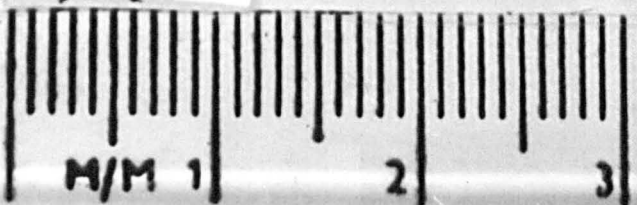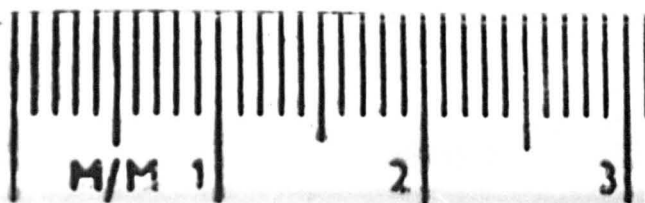
NEW KEY TO SOME COMMON, ADULT OTIORHYNCHUS

SPECIES FOUND ON GARDEN PLANTS IN GREAT BRITAIN

1. Under 9 mm. in length 2

   Over 9 mm. in length 5

2. Golden scales on brown elytra, thorax head and legs.
   ⋀-shaped keel on frons between scrobes .... O. singularis

   No scales on surface 3

3. Small, shiny weevil. Double tooth on prothoracic
   femur (rarely tripartite tooth). Red legs.
   Oval indentation on frons between eyes. Centre
   granules on thorax fused to form striations .... O. ovatus

   Rounded granules on thorax. One or no tooth
   on femur 4

4. Parallel-sided elytra giving squarish appearance.
   Striata prominent. Round granules on thorax.
   No tooth on femur. Scrobes closed. ()-shaped
   ridge on frons just below eyes .... O. rugostriatus

   More torpedo-shaped than above. One tooth on
   prothoracic femur. Granules fusing slightly
   on thorax. Scrobes open towards eyes. Slight
   central ridge from clypeus to frons between eyes .. O. rugifrons

5. Colour red. Surface pitted and punctured but
   not granulated. No tooth on femur. Large,
   torpedo-shaped weevil .... O. clavipes

   Colour black. Granulations on thorax and elytra.
   Groups of silvery hairs on striated elytra.
   Strong tooth on femur. Small rounded pit on
   frons between eyes .... O. sulcatus

d. DISTRIBUTION OF O. SINGULARIS

<u>IN BRITAIN</u>

This pest is reported from every NAAS region in Great Britain, and I myself have collected specimens of the adult weevil from every garden I have visited in summer in many different counties including:-

Staffordshire	Cambridge
Shropshire	Derbyshire
Lancashire	Gloucester
Westmorland	Kent
Cheshire	Herefordshire
Caernarvonshire	Derbyshire
Anglesey	Merionethshire

It would appear to be one of the commonest pests in Great Britain, and has probably not been recognised as such before because of its habit of feeding after dark. Perhaps much damage on herbaceous plants, shrubs and weeds has been wrongly accredited vaguely to "slugs" or "caterpillars" by the gardener. Most of the gardeners, even where the damage is common, have never seen and would not recognise the clay-coloured weevil.

<u>IN THE WORLD</u>

<u>O. singularis</u> is reported from all European countries, from the U.S.A. and Canada. I have seen evidence of its damage in the U.S.S.R. and U.S.A. It is probably universal and, being soil

coloured, able to tolerate a wide range of temperatures, to vary its
diet and reproduce parthenogenically, it has escaped detection and
control and most probably continues to spread.

Plate 32.

O. singularis feeding on leaves

of rhododendron.

Damage to outdoor rhododendron

by O. singularis.

SYMPTOMS AND DAMAGE TO PLANTS

i. ON RHODODENDRONS

The adult weevil bites the edge of the rhododendron leaf
a little way, then into the leaf, leaving irregular, elongated holes
as illustrated. (The damage is very similar to that caused by the
Vine Weevil, O. sulcatus, and although the latter may eat more per
capita, more damage to Rhododendrons is actually done by O. singularis
because they are normally present in greater numbers). New damage
has a light green margin to the hole and the weevil often returns to
the same spot on the succeeding evening to feed.   Some weevils out-
doors were marked with spots of white paint, then replaced on the
bush.   They were invisible during the day, but on the following even-
ing after dark returned up the rhododendron plant to the same leaves
as eaten on the previous night.

Older damage is surrounded by dead, brown patches.   Very
new leaves are not attacked, and most damage is seen on the current
year's, fully extended leaves, or on those already one year old.   The
rhododendron, being evergreen, often bears untouched leaves, newly
eaten ones and older leaves damaged and browning (Plate 32). Fox-
Wilson (1938) describes the damage on rhododendrons by O. singularis
as a partial gnawing of the midribs, a girdling of the petioles and a
feeding between the veins.   Very occasionally, especially on azaleas,
the petioles will be girdled, but the other descriptions of damage are
not substantiated by the work and observations of this weevil on

rhododendrons at Keele.

The weevil usually eats standing with its ventral side to the leaf edge, vertical to the earth.

DAMAGE ON OUTDOOR BUSHES

The following observations were made on different rhododendron bushes at Keele in August 1963, in order to compare the amount of damage caused by O. singularis on the leaves of outdoor rhododendrons.   Seven rhododendron bushes were labelled as follows:-

A)
B)   smooth, glabrous leaves

C)
D)   hairy, glaucous leaves

E)
F)   deciduous leaves

G   R. ponticum

Further details and photographs of some of these bushes are given in the following pages.

The total number of leaves on each bush was counted, then the number of leaves with weevil bites and the average number of bites per leaf were noted.

Plate 33.

Glabrous rhododendron leaves.

Plate 34.

Glaucous rhododendron leaves.

Plate 35.

Deciduous azalea.

TABLE xii

RESULTS

Bush	Variety	Total No. leaves	No. of damaged leaves	Average No. bites/leaf	% No. leaves eaten
A	Smooth	(231	160	2	69.26
B		(207	61	1.5	29.468
C	Hairy	(626	9	3.4	1.43
D		(360	4	2	1.11
E	"Queen Emma" deciduous	(528	166	3	31.44
F		(526	150	3	28.52
G	R. ponticum	224	181	6	80.80

From these results, and from other observations made, it can be concluded that out of doors the weevils appear to do most damage to the smooth-leaved types of Rhododendron, especially the species R. ponticum, which is often badly disfigured.

The deciduous leaves are attacked more in the bud and early-leaf stages in summer than in late summer and autumn.

Glaucous-leaved rhododendron bushes are hardly attacked by the weevil, and in the laboratory this result was endorsed.

In contrast, in the laboratory experiments the weevils showed a marked preference for the deciduous, azalea leaves over those of the smooth, glabrous type.

Probably some of the damage shown on the evergreen, smooth leaves was caused during previous years; on the azalea leaves, being deciduous, all the damage must have been caused this year. Therefore, although the smooth-type leaves show more damage, the weevil probably prefers the thin, azalea leaf as verified by laboratory experiments.

It was noticed that the azalea bushes and one of the smooth-leaved rhododendron bushes which were nearest to yew trees (Taxus bacata) were damaged more by weevil than those further away, but on examining the soil around these yew trees no adult or larval weevils were found.

<u>Plate 36.</u>

'

'

Two of the rhododendron bushes

used for leaf counts.

a. glabrous.

b. azalea.

TABLE xiii

RHODODENDRON BUSHES UNDER OBSERVATION

	A	B	C	D	E	F	G
Position and nearby vegetation	By path at lakeside, sycamore above, yew nearby	By lakeside; beech above, yew nearby	Willoughbridge, centre of wood near cherry, magnolia, brambles and bracken	Willough-bridge. No trees above. Azaleas nearby	In bed at top of grass slope, Keele. Other azaleas around. Yew tree nearby		Near path in woods at Keele
Soil	Loam and leafmould	Loam, mud humus	Mulch of bracken and oak leaves	Mulch of bracken	Clay and sand	Clay and sand	Loam and leafmould
Subsoil	Sandy	Sandy	Gravel	Gravel	Sand	Sand	Sandy
Size of bush	18" high 2' diam.	2'6" high 2'6" diam.	4' high 6' diam.	3' high 4' diam.	2'6"high 2' diam.	2' high 1½' diam.	3' high 2' diam.
Variety (if known)	?	G.waterer	?	?	Azalea "Queen Emma"	Azalea coccinea sp.	R. ponticum
Type of leaf	Glabrous, medium thin	Glabrous, 4-5" long 2" wide	Brown and glaucous underneath, round apex	Brown and glaucous below, green & glabrous above	Deciduous thin	Deciduous, thin	Glabrous
Approx. age of bush	Old bush cut down. Shoots 3 years	5 years	10 years	10 years	4 years	4 years	6 years
No. of leaves	231	207	620	360	528	526	224
No. of leaves damaged by weevil	160 with average 2 bites per leaf	61, 1-2 bites per leaf	9 very little on leaf margin. 3 bites per leaf	4, Av. 2 bites per leaf	166,Av. 3 bites per leaf	150,Av. 3 bites per leaf	181,av. 6 bites per leaf
Type of damage	Some from this year's, much from last year	Leaf margins and some petioles	Very little on leaf margin	Very little	Margins and petioles eaten, also buds & young leaves		Much of margins, some old, some new
Other remarks	15 leaves eaten by caterpillar	Some other damage to margin, probably cockchafer	Little caterpillar damage on 29 leaves	13 leaves damaged by caterpillars	No caterpillar damage, some weevils on branches and twigs		Very little caterpillar damage

Plate 37.

Damage to Primula, Bergenia,
Iris, Hemerocallis, Rhododendron
and Aster, by O. singularis.
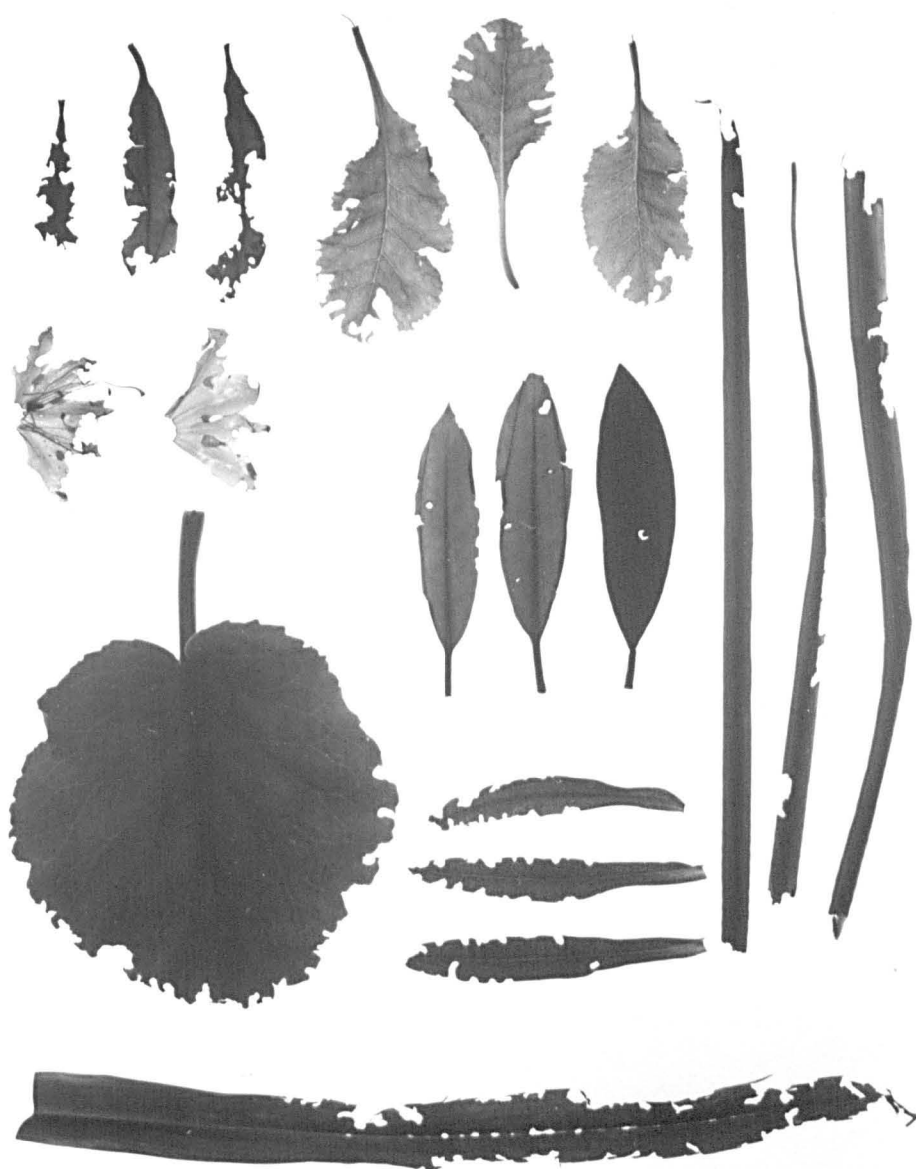
ii. DAMAGE TO PLANTS OTHER THAN RHODODENDRONS

Whilst observing O. singularis I have seen adult weevils and damage on the following (Plate 37) (Schofield 1962):

WOODLAND PLANTS

+	Ilex aquifolium	–	Holly
+	Rubus spp.	–	Wild raspberries
+	Chamaenerion angustifolium	–	Rosebay willow herb
	Tussilago farfara	–	Coltsfoot
	Urtica dioica	–	Stinging nettle
	Betula verrucosa	–	Silver birch
	Corylus avellana	–	Hazel
	Ulmus procera	–	Elm
	Acer pseudoplatanus	–	Sycamore
	Rumex crispus	–	Dock
	Digitalis purpurea	–	Foxglove
+	Primula vulgaris	–	Primrose

GARDEN PLANTS

+	Primula spp.	–	Primulas
+	Bergenia cordifolia	–	Elephant's ear
	Lupinus polyphyllus	–	Lupin
+	Iris sp.	–	Irises
+	Aster novi-belgii	–	Michaelmas daisy
	Hemerocallis fulva	–	Day lily
	Hydrangea macrophylla	–	Hydrangea

+ damage severe

Spiraea japonica	-	Spireae
Centaurea montana	-	Cornflower
Armeria maritima	-	Thrift or Sea Pink
Hosta glauca	-	Plantain lily
Ribes nigrum	-	Blackcurrant
Rubus idaeus	-	Raspberry

Willis (1964) mentions this weevil as a pest of strawberries (on which plants the larvae as well as adults cause damage when in large numbers). He also describes damage on top fruit trees:- destruction of buds, blossoms and new shoots; damage to buds on newly grafted scions; feeding on young bark and girdling of stems. This latter also occurs in young forest tree nurseries. Petiole severance is a common occurrence in blackcurrant and strawberry plants, and even blossom-truss severance occurs in some soft fruits.

Hill (1952) describes O. singularis causing damage to young canes, petioles and flowering laterals of raspberries in Scotland. Massee (1942) writes of the damage to the shoots of hops. In the Oxford Ecological Survey, Bureau of Animal Population, the species is recorded from oak, ash, sycamore, conifers, grass and even from the nest of a red squirrel!

The damage by O. singularis on plants other than the rhododendron is mainly to the leaf margin. Often the damage is irregular and severe. Sometimes (as on young Michaelmas daisies)

the buds are destroyed and the plants eaten almost down to ground
level.   On coltsfoot the weevile ate holes in the lamina and on
azaleas petioles were eaten through.

The clay-coloured weevil is therefore polyphagous and one
of the most destructive pests in the gardens of Britain.   Its
importance has been greatly underrated by horti/culturists in the past.

Plate 38.

a. Rubus sp.

O. singularis damage on:

b. Rosebay Willow-Herb
Chamaenerion angustifolium

Plate 39.

a. coltsfoot
   Tussilago farfara.

O. singularis damage on:

b. birch
   Betula sp.

e. EMERGENCE, COLLECTION AND EXTRACTION FROM SOIL

OF WEEVIL O. SINGULARIS

EMERGENCE

First damage to leaves was noted on 6th May 1963, on
R. ponticum, and the first adult O. singularis caught on 16th May.
Collecting continued regularly until 11th October 1963.

In other years the dates were similar.

COLLECTION

a.   The weevils emerge at dusk, walk along and up the stems
and begin eating at once.   They can   easily/hand picked from the
leaves and do not drop when a torch is shone on to them.   They res-
pond quickly to vibrations of the bush and immediately fall to the
ground, folding their legs underneath them, lying still.   Once on
the soil they are extremely difficult to see because of their colour
and the fact that they often have soil adhering to the hairs on the
fused elytra.

b.   The bush can be shaken or beaten over a cloth or net, the
weevils falling on to them, but the insects soon walk to the edge of
the net and fall over the side on to the ground.

It is interesting to note that when the weevil, lying
apparently dead on the soil, is picked up carefully by hand or by
tweezers, it extends its legs and antennae to their fullest extent,
probably as a defence mechanism to frighten away the attacker (Plate 42).
p.253.
When collected, weevils can be kept in sealed jars feeding on R. ponticum

for many months. Metal lids are better than cork, rubber or paper because the weevil will eat these materials. Although they can sometimes survive without fresh air and food supply for up to eight months, they naturally thrive better with both these.

EXTRACTION FROM SOIL

The following methods of extraction were tried:-

a. Sieving soil and examining by hand

This was done on a mechanical shaker with different meshed sieves. The soil was often too wet to do this immediately and needed to be dried out beforehand. Simple method, but laborious, and very few adult weevils or larvae were extracted by this method.

b. Tullgren funnel

A large glass funnel, into which soil is placed on some large-meshed cloth material, has above it an ordinary tungsten bulb which is lit day and night. As the soil dries at the top, the insects are driven downwards to the moist soil and may crawl through the cloth and fall down the slippery funnel into the flask below.

c. Modified Tullgren apparatus

Basically a funnel, as above, placed inside a plywood box. The bulb used is a carbon incandescent lamp placed 15 cm. above the funnel.

The results obtained with this were slightly less favourable than the simple Tullgren funnel.

d.   <u>Salt and Hollick flotation method</u> (1944)

This apparatus is based upon Ladell's magnesium sulphate flotation technique, and a small version was made in the laboratory at Keele and many soil samples washed through each year.

The apparatus is described and illustrated in McE. Kevan (1962).

Some soil animals were recovered from the liquid, but method (b), followed by (a) were the most successful for <u>adult</u> weevils. Method (d) recovered some of the <u>larvae</u> and (a) was the only one, besides hand sorting, which recovered any <u>pupae</u> from the soil.

f.   CONTROL

CULTURAL

The soil around young rhododendron bushes in the nursery should be kept well hoed and free from leaf litter.

MECHANICAL

On a small scale, handpicking the weevils from the leaves at night gives a very good control.   Shaking the bush over a sheet of paper after dark will dislodge the weevils, but the paper has to be gathered up quickly if the insects are not to escape from it.

Traps of crinkled tissue paper, woodwool, sacking, etc. have proved effective in the laboratory on a smooth surface where the weevils have no other place to hide during the day, but outside they prefer leaf litter and the traps are not so effective.   On level, hoed soil with a fine tilth they may prove quite useful.

CHEMICAL

Results of chemical insecticidal tests carried out in the laboratory in 1962 are given below.   DDT liquid spray used at twice the normal recommended strength for most other garden pests was very effective.

N.B.   Since these tests were completed, it has been recommended by the Department for Education and Science (1969) that DDT be longer be used by the amateur grower, and therefore Malathion, although not so quick acting, should be used in preference to DDT.

Hill (1952) also recommended DDT, as does the M.A.F.F.

(Rev. 1968) in its advisory leaflet No. 57.   It also suggests dusting the holes with BHC before planting rhododendrons.

TO TEST THE EFFECTS OF VARIOUS INSECTICIDES ON ADULT

O. SINGULARIS ON THE LEAVES OF RHODODENDRON

Commercial brands of insecticides containing one of the following were used at the strengths recommended by the producers. DDT liquid was then tested at twice the recommended dosage.

    a.   Malathion Liquid (Murphy)   (1 fl. oz. in 2 gall. water)

    b.   DDT Liquid (Portland 20%)   (1 fl. oz. in 2 gall. water)

    c.   DDT dust 5%   As supplied

    d.   DDT Liquid at twice the normal strength (1 fl. oz. in 1 gall. water)

Two cages, each with 5 weevils, were set up for each chemical to be tested as shown:-
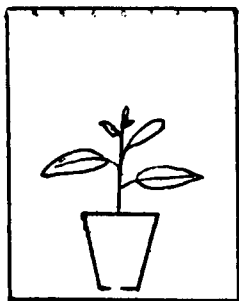
1.   Chemical solution
    watered on to
    plant and soil,
    or plant and soil
    dusted.
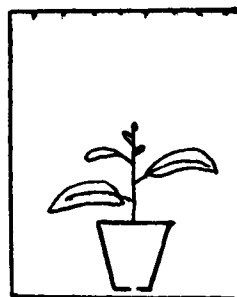
2.   Control plant
    watered normally
    5 weevils present.
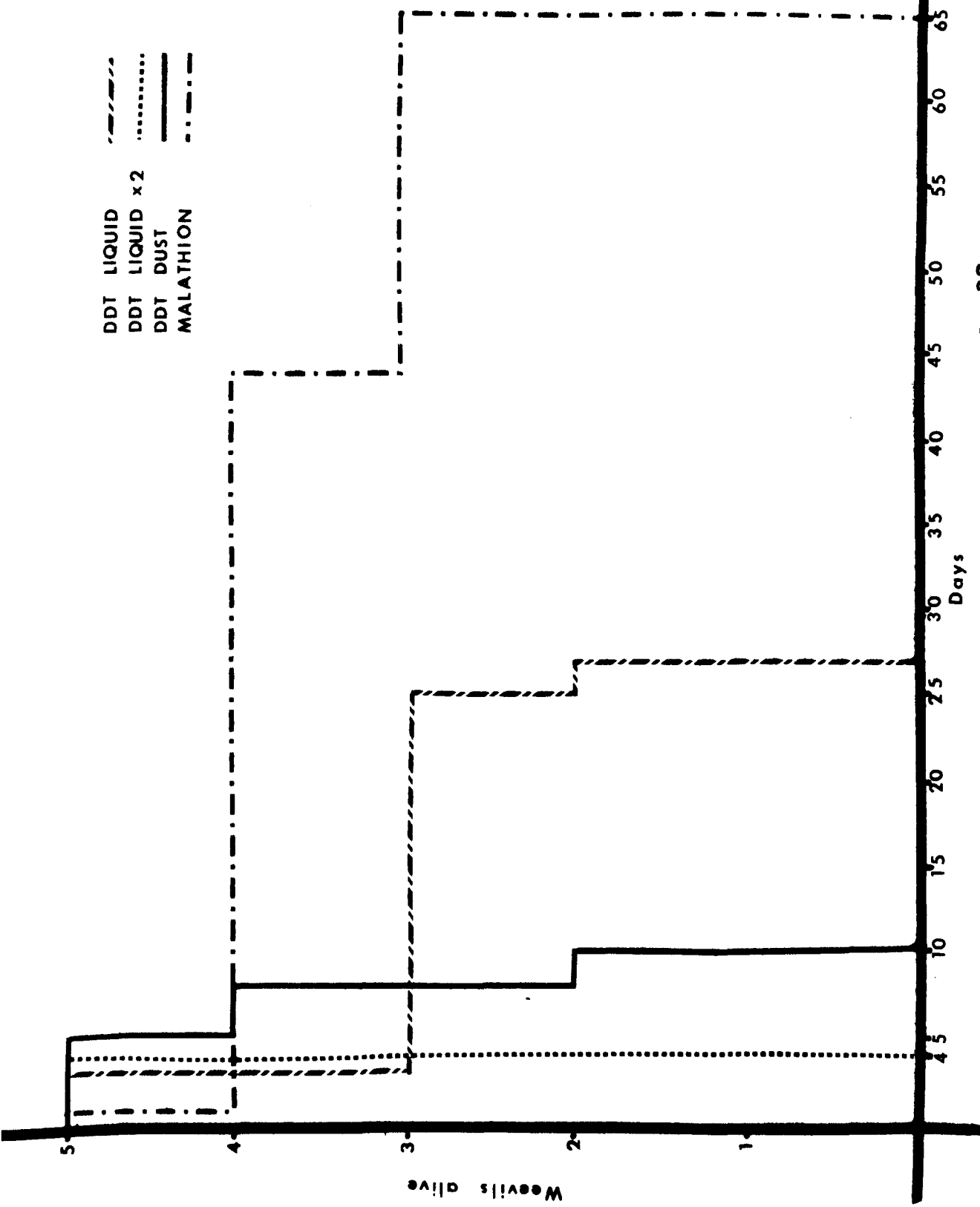
Fig. 28

The individual results are shown on the diagram (Fig.28)
Liquid DDT at twice the normal strength was by far the most effective,
killing all the weevils in only 4 days, followed by DDT dust which
took 10 days to complete the killing of all five weevils, although they
were almost dead and on their backs after only one day.

The normal liquid DDT took 11 days, but after six days
all the insects were knocked down and dying. The systemic insecti-
cide took very much longer to be effective.

The white DDT dust was the only one to appear unsightly
on the plants.

It was very noticeable that the DDT acted also as a
deterrent to the weevils, and none of the leaves was eaten on any
plant. The leaves where Malathion was used were badly eaten by the
weevils before they died.

O. SINGULARIS

SURVIVAL TEMPERATURES IN THE LABORATORY

10 weevils were placed in each of the following temperatures
for four weeks in petri-dishes. The humidity was kept high.

$$-20\ ^{\circ}C,\ -10\ ^{\circ}C,\ -4.5\ ^{\circ}C$$
$$6\ ^{\circ}C,\ 14\ ^{\circ}C,\ 21\ ^{\circ}C,\ 26\ ^{\circ}C,\ 31\ ^{\circ}C.$$

The weevils survived at all temperatures except -10 $^{\circ}$C, -20 $^{\circ}$C
and 31 $^{\circ}$C. At -4.5 $^{\circ}$C the weevils were apparently dead but revived
on thawing. In his studies on the grain weevil C. granaria, Mathlein
(1939) noted a similar state at +4.5 $^{\circ}$C when the insects appeared
dead, but revived on being placed in a higher temperature and lived
another 80 days.

It would appear that maximum temperature for suvival is above
26 $^{\circ}$C, but less than 31 $^{\circ}$C and the minimum between -4.5 $^{\circ}$C and -10 $^{\circ}$C,
probably nearer to -4.5 $^{\circ}$C.

Lethal temperatures may vary according to the thermal history
of the insects, but in this case all the weevils had been caught on
the same evening outdoors in similar surroundings. We can presume
they had all undergone similar acclimation.

Diapausing and hibernating stages of overwintering insects show
greater cold-hardiness (Bursell 1964) accounted for by the cessation
of feeding. Therefore outdoors in the soil in winter the weevil may
be able to withstand lower temperatures than those given above.

One can surmise that the depth at which hibernation takes place
in the soil in winter will depend on the soil temperature at different
levels, the weevils lying deeper in the soil in a bad winter.

DETERMINATION OF THE POSITION OF ADULT WEEVILS, O. SINGULARIS,

AROUND A RHODODENDRON PLANT IN SOIL, DURING THE DAYTIME.

Outside, in normal conditions in a wood containing rhododendrons, it has been very difficult to discover the exact location of the weevils during the daytime and judging from the way in which weevils aggregate together in a tin or jar when no soil is available, it would lead one to suspect that they aggregate in the soil. In examining random samples of soil from various depths around the eaten rhododendron bushes, I have not come across such an aggregation.

This experiment, using a plant in artificial conditions, was set up to help confirm or deny this theory.

A small plant, 18" high, of R. wardii was planted in the laboratory in peat and sand contained in a glass, rectangular tank. Ten weevils, marked on their backs with a spot of white paint for easier recovery, were introduced into the tanks. Another similar tank was placed over the plant and the two sealed together with adhesive tape.

Each week the weevils, some of which had been feeding on the leaves of the plant during the night, were sought and their sites noted.

In all cases the soil was sieved and examined carefully inch by inch.

The first three treatments were in the laboratory, the fourth on the roof of a building where the night and day temperatures varied a little more than inside.

RESULTS

TABLE xiv

Experiment No.	Date	Duration in days	No. of weevils introduced	found	Depth	Aggregating
a.	26.6.64	10	10	5	Top 1"	No
b.	6.7.64	28	10	3	Top 1"	No
c.	16.9.64	28	12	1(dead)	Top 1½"	No
d.	15.7.65	7	10	5	Top 1½"	No

Results and conclusions

In all four instances, half or more of the original number of introduced weevils were not to be found, although the soil was examined extremely carefully by mechanical shaker and by hand. The adhesive tape had not been removed or damaged and there appeared to be no possible way of escape from the glass containers. No obvious parasites or predators were found in the soil. This disappearance must be accounted for by death and disintegration or by cannibalism amongst the weevils.

Of the remaining weevils, all were found in the top 1½ inches of soil and in no instance were they in an aggregation.

It would seem that the aggregations previously noted in glass jars are not normal in the soil, but that during the daytime the adult weevils hid in the soil, their depth being dependent on temperature.

FACTORS AFFECTING FEEDING

The following four experiments were set up in the laboratory during 1963 and 1964 to discover what factors influence the amount and type of feeding carried out by Otiorhynchus singularis.

1. Determination of the amounts of different leaves eaten by 30 weevils.

2. To determine which type of rhododendron leaf the adult weevil prefers to eat when allowed a free choice.

3. Experiment to discover whether the weevil Otiorrhynchus singularis prefers to feed in darkness or light.

4. Olfactory experiment.

    Conclusions.

O. SINGULARIS FEEDING EXPERIMENTS

1.   Determination of the amounts of leaf eaten by 30 weevils

The experiment began on 24th May 1963 and continued, for the first part, for ten weeks until 1st August 1963.

Thirty adult weevils, <u>Otiorhynchus singularis</u>,which had been caught during the hours of darkness, from Rhododendron bushes at Keele immediately preceding the experiment, were placed singly in petri-dishes. Two pieces of damp filter paper were placed in each dish to preserve a high humidity, constant for each animal.

The dishes were then labelled 1 - 30.

1 - 10 were fed on smooth or glabrous rhododendron leaf:

11 - 20 fed on glaucous leaf which was hairy on the underside:

21 - 30 fed on deciduous, azalea leaf.

In each dish was placed a circle of the appropriate leaf of 1 cm. diameter, area 0.786 sq. cm. The dishes were examined daily and a new leaf inserted when the previous one was completely eaten.

At the end of each seven day period any remaining leaf portions were removed and placed on transparent tape and labelled. They were then projected and magnified x 10 by use of a modified microprojector and the outlines drawn on paper and measured by means of the planimeter. From the areas measured, the amount of leaf eaten by each weevil was

calculated weekly $n \times 0.786 - x$ cm^2 where x is the amount of leaf left uneaten and recorded. (See Factorial Experiment p. 193).

Fresh, complete, leaf circles were inserted as the others were removed each week. The circle of leaf was cut by using a cork-borer.

The maximum and minimum temperatures in the laboratory were recorded daily, and from these the daily and weekly averages calculated.

Because of structural alterations to the building, the insects had to be moved from one laboratory to another where the temperature was on average lower. Added to this, the outside temperatures rose at the beginning of June and fell again afterwards. Thus, instead of there being a steady rise in temperature during the late spring and summer as might normally have been expected, the average temperature rose, fell and gradually rose again during this ten-week period, as can be seen on the graph.

Results.

TABLE XV.

Week No.	Average amounts of leaf eaten per weevil. in cm^2		
	Weevils.		
	1 - 10	11 - 20	21 - 30
	glabrous	glaucous	deciduous
1	0.118	0.109	0.358
2	0.349	0.867	1.059
3	0.939	1.175	2.865
4	0.541	1.403	2.619
5	1.660	0.784	1.047
6	1.323	0.482	0.536
7	0.347	0.390	0.353
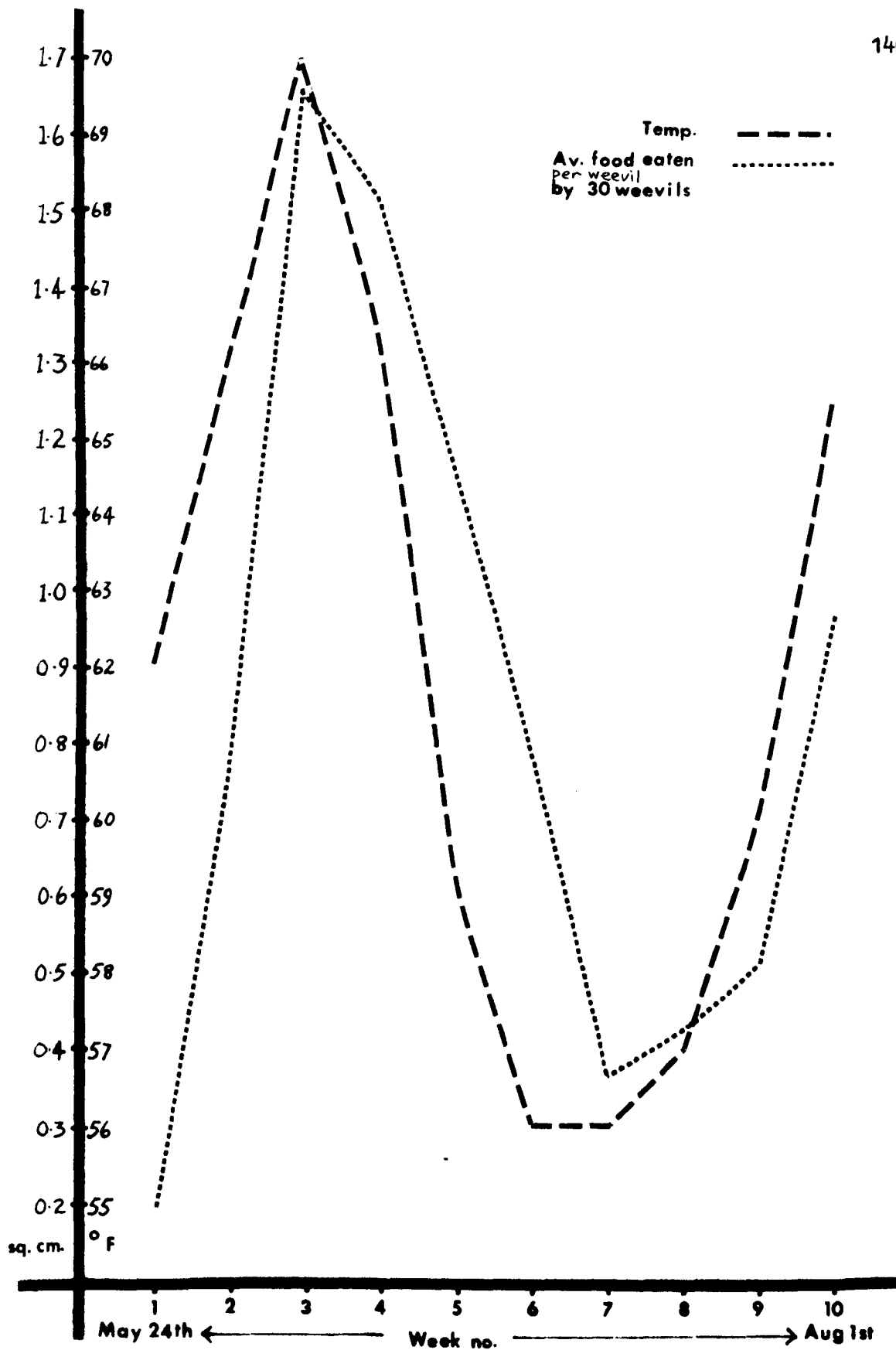
Fig. 29.

Week No.	1 - 10 glabrous	11 - 20 glaucous	21 - 30 deciduous
8	0.412	0.397	0.459
9	0.295	0.502	0.759
10	1.155	0.795	0.933
Total of average amounts eaten by 10 weevils	7.209	6.904	10.988
Av. of 10 weevils	0.721 cm^2	0.690 cm^2	1.099 cm^2

TABLE xvi

Week No.	1963 Date	Temperature $^\circ$F	Average per weevil eaten by 30 weevils cm^2
1	24.5 - 30.5	62	0.195
2	31.5 - 6.6	66	0.758
3	7.6 - 13.6	70	1.659
4	14.6 - 20.6	66.5	1.521
5	21.6 - 27.6	59	1.164
6	28.6 - 4.7	56	0.780
7	5.7 - 11.7	56	0.363
8	12.7 - 18.7	57	0.423
9	19.7 - 25.7	60	0.519
10	26.7 - 1.8	65.5	0.961

From the table and graph comparing the average amount of the three types of leaves eaten by the weevils, it is apparent that those feeding on the deciduous leaves ate more than either those on the glaucous or glabrous leaves. The average amount eaten of the latter two types was very similar, the glabrous type being only slightly more than the glaucous.
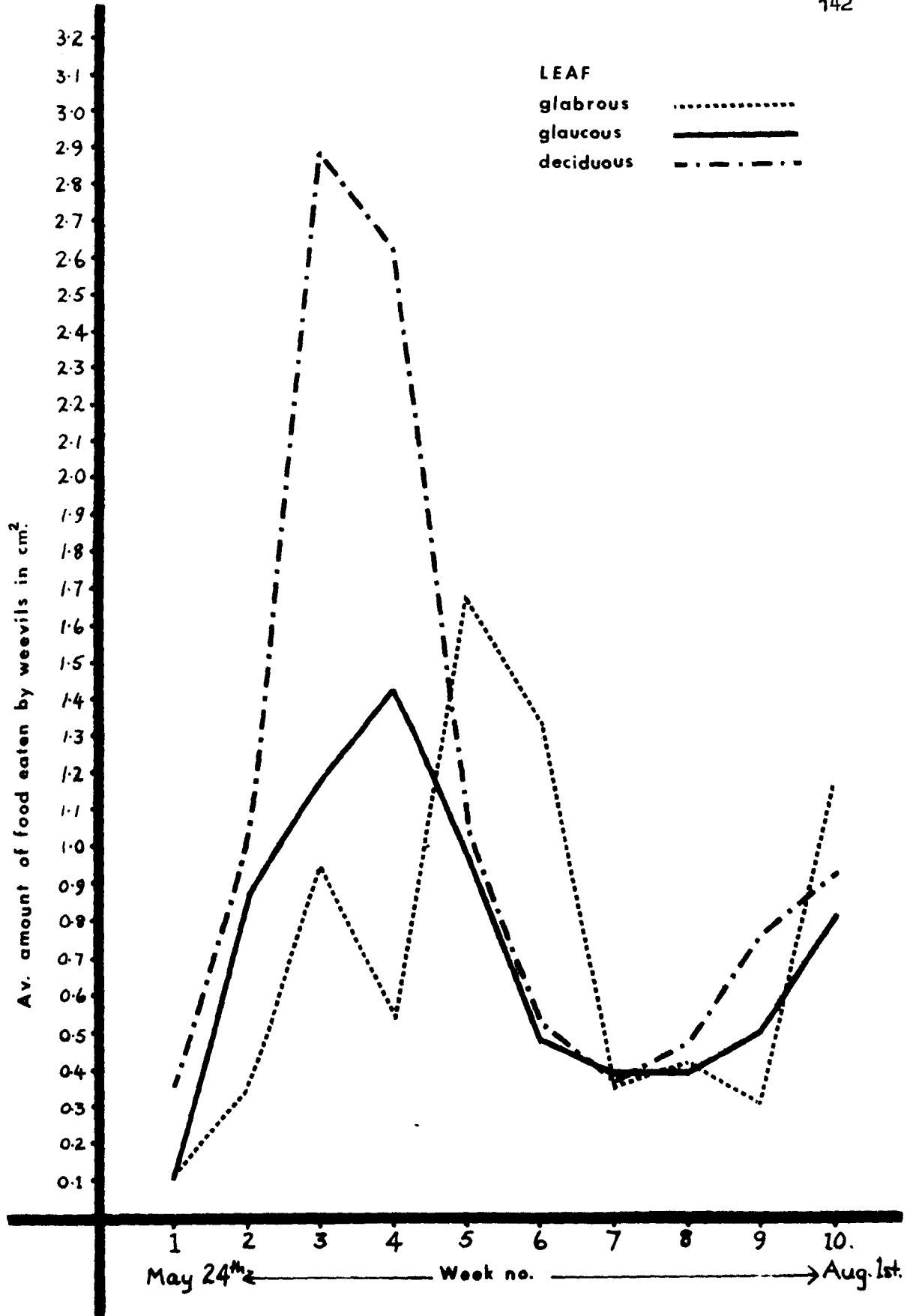
Fig. 30.

These results agree with those shown in the "Preference" experiment where the food was chosen at random and will be discussed in that section.

The graph shows that, on the whole, more of each type of leaf was eaten as the temperature rose, and less at lower temperatures. The deciduous-leaf graph follows this closely, whilst the glaucous type only diverts in the fourth week when the temperature falls, but the average amount eaten still increases. The graph of the smooth, glabrous leaf varies from normal by rising sharply in the fifth and falling slightly in the ninth week. This latter fall in amount eaten may be due to a lowering of the relative humidity inside the dishes during the week when the filter papers tended to be dryer than usual.

Conclusions.

By comparing the average amount eaten by all thirty weevils with temperature, as in the preceding table and graph, it can be concluded that the weevil eats more at the higher summer temperatures, and as the temperature falls, so does the amount eaten. The weevil consumes more area of deciduous leaf than of the glabrous or glaucous types.

2. TO DETERMINE WHICH TYPE OF RHODODENDRON LEAF THE ADULT WEEVIL PREFERS TO EAT WHEN ALLOWED A FREE CHOICE

The experiment commenced in the laboratory on 27th May 1963, and continued for ten weeks until 5th August.

Eight adult weevils, Otiorhynchus singularis, were numbered 31 - 38 respectively. Weevils 31 - 35 were placed in plastic and metal cages and 36 - 38 in petri-dishes (Fig. 31).

In each container was placed three circular pieces of rhododendron leaf, diameter 1 cm., area 0.786 sq. cms:-

(a) glabrous or smooth (R. ponticum):

(b) glaucous or hairy on under surface (type R. glaucophyllum).

(c) deciduous (Azalea series and luteum subseries).

In the cages the leaf circles were placed at the top of the cane on pins, the weevil having to walk up this cane to reach the food, thus ensuring randomization. Damp filter paper was placed in both the cages and the dishes to keep the atmosphere moist.

The leaf circles in 31 - 35 tended to dry out quicker than those in 36 - 38 and this may account for the average amount eaten in the cages being less than that in the petri-dishes. (Table xviii).

Adhesive tape had to be fastened to the rim of the cages, or the insects were able to escape. Newspaper was placed on top to keep out the dust. The food was examined daily and as a circle was completely eaten it was replaced.

After every seven days any remaining circles or parts of circles were placed on transparent adhesive tape covered with more tape and labelled. Three complete, fresh leaf circles were then substituted

Apparatus used in Food Preference Experiment.

Weevils 31 - 35 Cages.

perforated, metal lid.
adhesive tape.

leaf circles pinned to cane.

bamboo cane.

transparent plastic.

metal base.

cork disc.
petri-dish containing moist
filter paper.
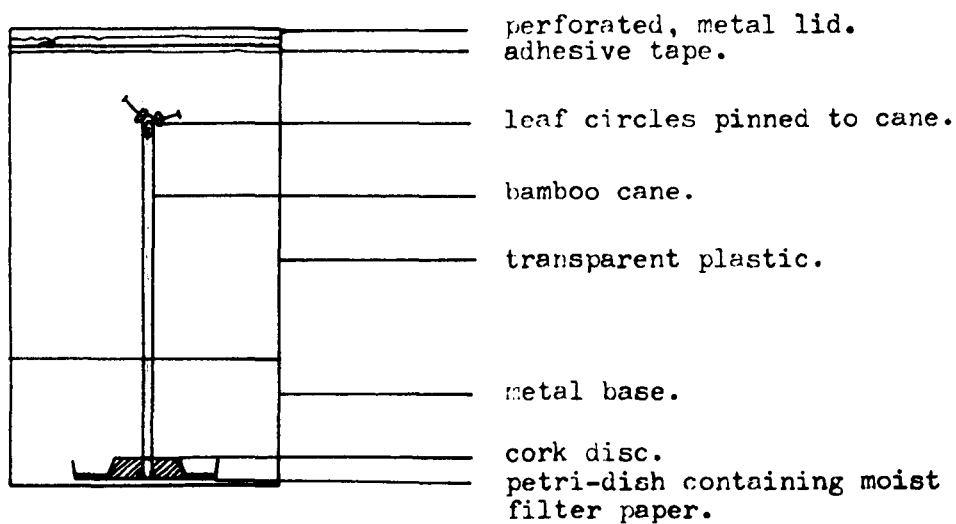
Weevils 36 - 38. Petri-dishes.

Glass petri-dish with lid.

leaf circles.
moist filter paper.
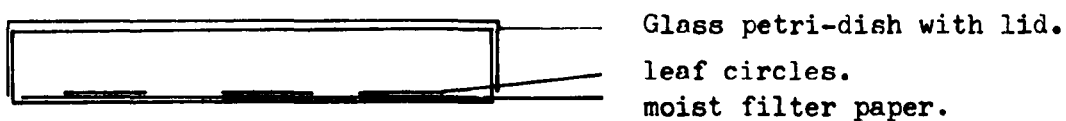
Fig. 31.

in the containers, and the portions of leaf dealt with as for the

Factorial Experiment.

The average amount in sq. cm. of each type of leaf eaten per week

is shown below:

TABLE xvii

Week No.	1963 Date	Average amount of leaf in cm^2 eaten per week by all weevils			Total of averages
		a	b	c	
		glabrous	glaucous	deciduous	
1	27.5 - 2.6	.077	.018	.290	0.385
2	3.6 - 9.6	.303	.174	.978	1.455
3	10.6 -16.6	.222	.405	1.236	1.863
4	17.6 -23.6	.429	.402	.997	1.828
5	24.6 -30.6	.279	.115	.324	0.718
6	1.7 - 7.7	.490	.108	.616	1.214
7	8.7 -14.7	.049	.167	.110	0.326
8	15.7 -21.7	.229	.246	.357	0.832
9	22.7 -28.7	.248	.146	.447	0.841
10	29.7 - 4.8	.029	.236	.548	0.813

Total of
averages   =   2.355   2.017   5.903

Overall average
for 10 weeks =   0.236 cm^2 0.202 cm^2 0.590 cm^2

From these results, and from those obtained from experiment

(p. 148) 1, it can be seen that under laboratory conditions the weevil

O. singularis shows a marked preference for the deciduous, azalea leaf,
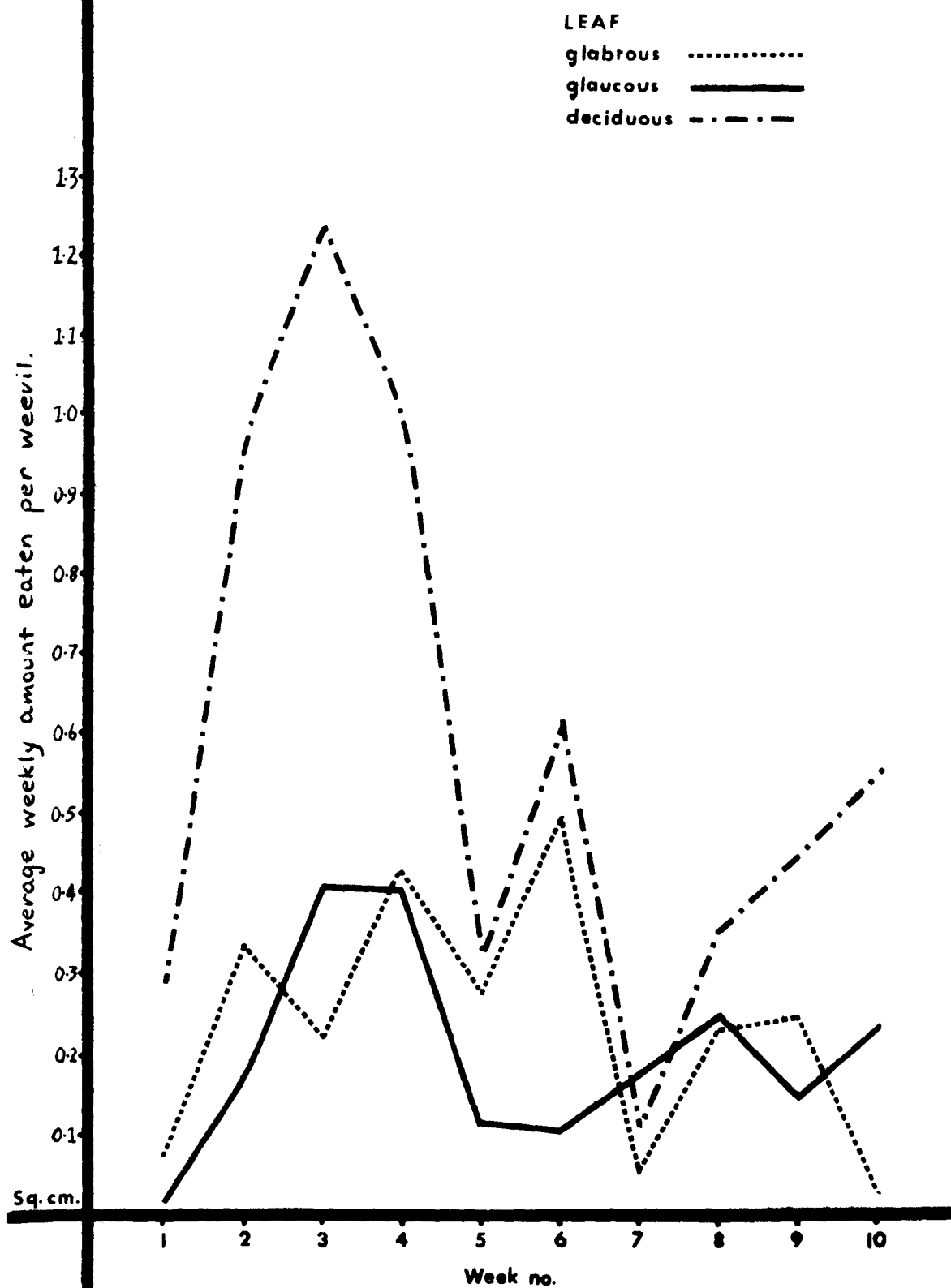
Fig. 32.

followed by a lesser one for the glabrous type, whilst only a relatively small proportion of the glaucous type of leaf was eaten. Whether the weevil was given a free choice of food or provided with only one type of leaf, appears to make little diffence to the amounts of each type of leaf eaten.

Considering the reasons behind the preference for deciduous, azalea leaf, transverse sections of the three types of leaf were made and are shown in fig 33 . The first noticable point is that the azalea leaf is narrower than the other two types so that although in square centimeters the weevils may eat more area of deciduous leaf, in volume the amount of difference is probably not so great. On the other hand, the azalea leaf has a more uniform density than the other two, which contain much spongy mesophyll. Secondly the azalea leaf has no thick cuticle on top of the upper epidermis as have the glaucous and glabrous types, neither has it such a wide layer of small celled, thickened epidermal cells. This fact would make the deciduous leaf mechanically easier to bite and cut with the mandibles. The hairy indumentum on the lower surface of the glaucous type would prove a further physical barrier for the weevils' mouthparts.

Initially the weevil is probably attracted to the deciduous leaf or repelled from the glaucous type by smell, then by taste, but it could be the association of a certain smell with a thick cuticle or hairy lower epidermis which steers it away from the glabrous and especially the glaucous type.

It is of interest to note that no two weevils eat in the same manner or even at the same time or temperature (fig 34). This has
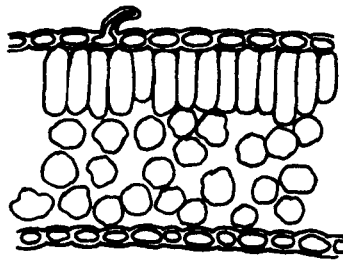
T.S. of deciduous, azalea leaf.

T.S. of glabrous leaf.

cuticle
upper epidermis
palisade
mesophyll.
spongy
lower epidermis

T.S. of glaucous leaf

hairs forming indumentum.

Fig. 33.
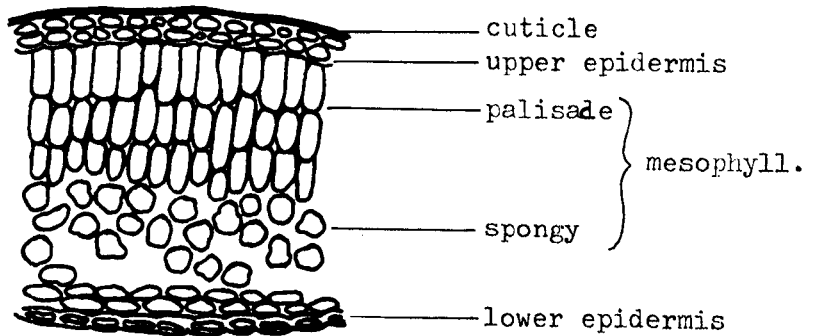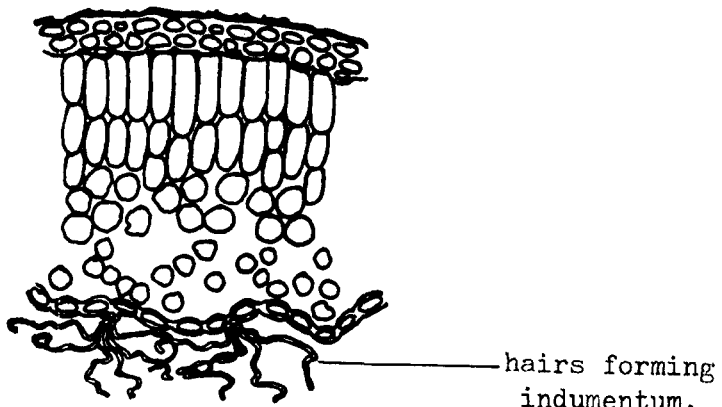
been noticed throughout all the experiments and it is quite impossible
to write honestly about an "average" weevil.

TABLE: xviii

Amount of food eaten by weevils

Week No.	31 – 35 in cages		36 – 38 in petri dishes	
	total cm^2	average cm^2	total cm^2	average cm^2
1	3.074	.615	0	0
2	5.382	1.076	6.257	2.086
3	7.060	1.412	7.843	2.615
4	7.629	1.526	6.990	2.330
5	3.754	0.751	1.996	0.665
6	8.691	1.738	1.001	0.334
7	1.435	0.287	1.174	0.391
8	1.226	0.245	5.426	1.809
9	0	0	6.723	2.241
10	1.263	0.253	5.247	1.749
Total		7.903		14.220

The R.H. in the cages 31-35 was lower
than in the petri dishes 36-38.
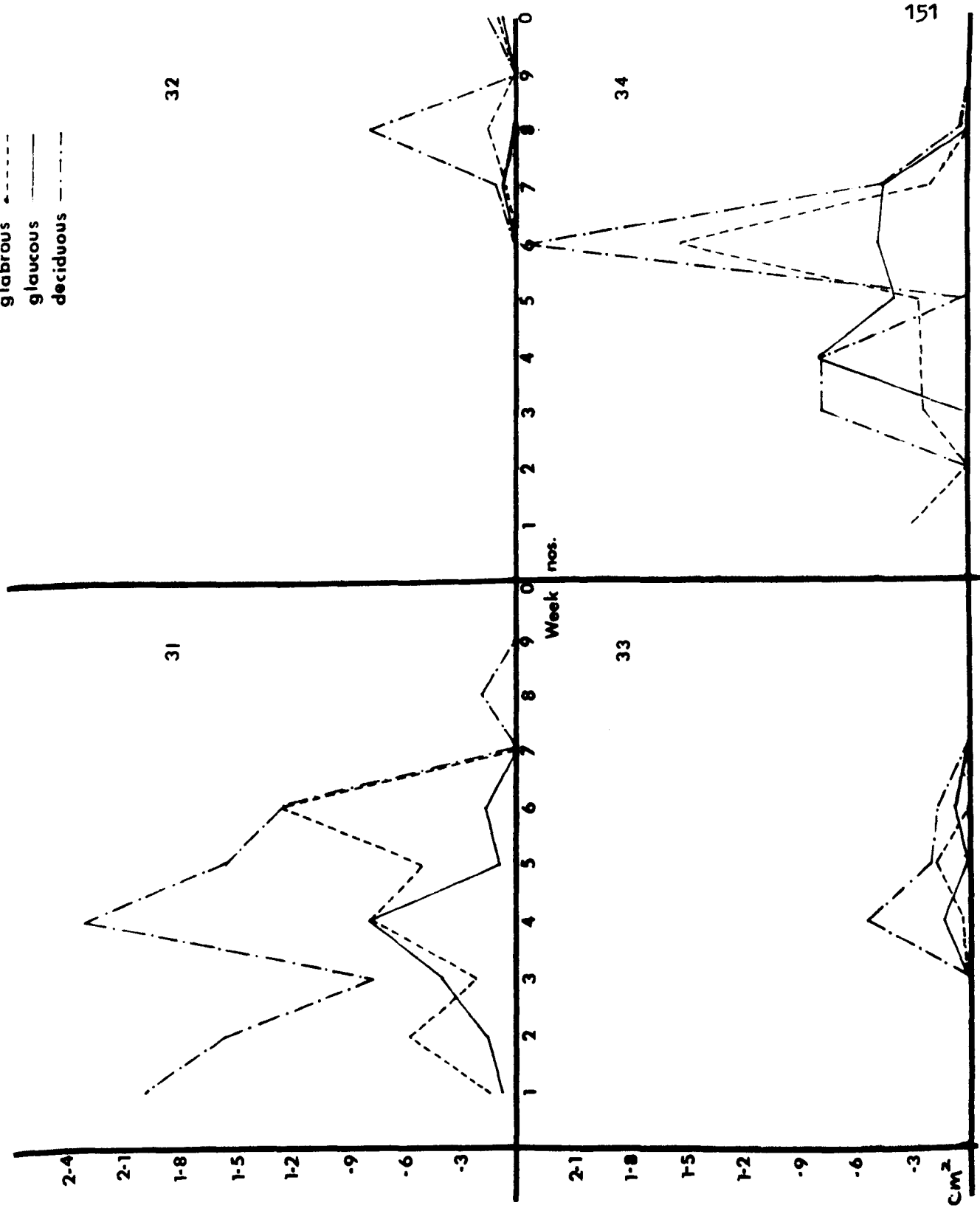
Amount eaten by individual weevils nos. 31 - 34.

Fig.34.

3.   EXPERIMENT TO DISCOVER WHETHER THE WEEVIL OTIORRHYNCHUS

SINGULARIS PREFERS TO FEED IN DARKNESS OR LIGHT

In natural conditions outside, weevils are found eating the leaves of Rhododendron and other plants only after dark, but in petri dishes in the laboratory they have been seen to be eating during the daytime as well as at night. The following small experiment was devised to count the number of times certain weevils (which were selected at random from those caught at night on R. ponticum) ate in the dark and in the light when given complete freedom of choice.

The insects were kept in a north facing room where very little variation of temperature took place, and where the uncovered tube received normal daylight and night intensities of light.

A large tube with two smaller tubes at the end (shown in the diagram (35) for Olfactory Tests) was used for each weevil, the insect being placed in the closed end of tube C.

One tube was covered with silver foil, cutting out any light, the other tube was left transparent.

Circles of leaf 1 cm. in diameter were freshly cut from a leaf of R. ponticum each day and one placed at the closed end of each small tube. The tubes were revolved every day to eliminate directional influences.

Once a day the tubes were examined and if the weevil had been feeding, it was noted whether this was in tube A or tube B.

The results are as follows:-

TABLE ixx

Weevil No.	No. of times feeding in		
	Light,	Dark.	
1.	20	15	Experiments begun 24/5/64 for
2.	11	11	10 weeks.
3.	7	4	
4.	3	5	Experiments begun 28/8/64 for
5.	7	5	4 weeks.
6.	8	7	
7.	7	3	Experiments begun 17/5/65 for
8.	9	9	4 weeks.
9.	10	2	
Total:	82	68	
% of times	54.83%	45.17%	

It would appear that light or darkness do not significantly influence the feeding of O. singularis in the laboratory, a fact later confirmed in the Factorial Experiment.

Two other points noted during this experiment were:

a. Weevils tended to eat the rubber bung at the centre of the tubes and in all cases laid eggs soon after eating the rubber.

b. The totals for feeding in the left hand or right hand tube L.H. 49.06% R.H. 50.94% were very similar and therefore the direction of feeding does not seem to be an influence.

This experiment was set up in May 1964 for 4 weeks, to try and determine whether or not the weevil O. singularis was attracted to its food by use of the olfactory organs.

Twelve 12-inch glass tubes were fitted with a large rubber bung (although the weevils may eat the rubber in very small amounts occasionally, they eat less of this than cork, so bungs of the latter material are to be avoided), and into the bung were placed two smaller glass tubes as in the diagram.

The selected weevil, caught at night from R. ponticum, was placed at the closed end of the large tube. At the closed ends of the smaller tubes were placed circles of leaf 1 cm. in diameter, one tube (labelled with a dot to distinguish it) having in it R. ponticum and the other R. fulgens or R. wardii. All circles were cut from the centre of leaves and had no natural leaf margin on their circumference.

The tubes were laid horizontally on the bench and turned each day, thus reversing the positions of A and B and eliminating any purely directional attraction of the leaves for the animals.

The results of these experiments are shown below:

a.   6 tubes R. ponticum in tube A) - % of times leaf eaten 82.76%
     6 tubes R. fulgens in tube B) - "   "   "   17.24%

b.   6 tubes R. ponticum in tube A) - "   "   "   58.54%
     6 tubes R. wardii in tube B) - "   "   "   41.46%

From these results it would appear that the insect could be attracted to R. ponticum and repelled from R. fulgens and to a lesser extent by R. wardii by the smell of the cut leaf. To the human nostrils
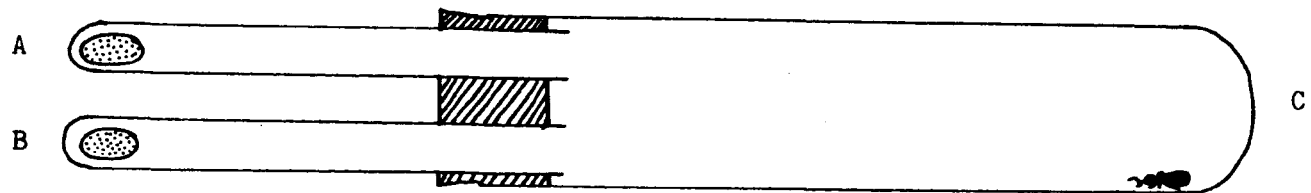
Diagram of the tubes used in the Olfactory experiments.
(not to scale).

Tube   A   :   R. ponticum.

Tube   B   :   other plant leaf, R. fulgens or R. wardii.

Tube   C   :   large tube in which weevil is placed.

Fig   35.

the leaves do emit a different smell from each other, R. fulgens
being the most pungent of the three.

In natural conditions, outside on the rhododendron plant or other
host, it is noticeable that the weevils seem to return to eat at night
to a leaf which is already damaged and has an eaten margin. This
could perhaps be that the escaping plant liquids emit an odour
attractive to the weevil, or simply that it is mechanically easier
for the insect to eat at an already indented margin, or more likely
a combination of both these factors.

FACTORS AFFECTING FEEDING

CONCLUSIONS

From the preceding experiments the following conclusions can be drawn:

1. More food is eaten when the temperature rises, less when the temperature falls.

2. More food is eaten in the petri dishes than the cages in experiment 2, probably due to the difference in humidity between the two; therefore the higher the humidity the more food eaten.

3. O. singularis prefers to feed on deciduous azalea, glabrous and glaucous leaves in that order. This result does not depend on whether the weevil is given free choice of leaf type or not.

4. The azalea leaf has no thick cuticle and only a thin epidermis on both the upper and lower surfaces and it is probably easier for the weevil to bite into than the other two types.

5. The weevil shows no marked preference for feeding in darkness or in light, in the laboratory.

6. O. singularis is probably attracted to some varieties of rhododendron and repelled by others due to the olfactory sense.

FACTORS AFFECTING OVIPOSITION

During the ten weeks 24th May – 1st August 1963, the number of eggs laid by each of 30 weevils (labelled 1 – 30) was recorded daily. At the same time the weevils were offered 1 cm. diameter circles of rhododendron leaf, and the temperature in $^{\circ}F$ was recorded daily.

The O. singularis weevils were kept individually in petri dishes in the laboratory. Once a week the filter paper in the dishes was changed and at that time the eggs and any larvae were carefully transferred to the new paper by means of a sparsely-haired brush. Many of the eggs tended to become covered with a white fungus and consequently not to develop. These mouldy eggs were discarded daily. In a very few cases, the number of eggs decreased slightly suggesting that at these rare times the adult weevil must have eaten the eggs.

The circles of food were replaced weekly and the remains measured as in the Factorial Experiment (p. 193). New circles were inserted in less than a week if the weevil had already consumed the original one.

The dates corresponding to the week numbers are:-

Week 1	24.5 – 30.5.63	Week 6	28.6 – 4.7.63
2	31.5 – 6.6.63	7	5.7 –11.7.63
3	7.6 – 13.6.63	8	12.7 –18.7.63
4	14.6 – 20.6.63	9	19.7 –25.7.63
5	21.6 – 27.6.63	10	26.7 – 1.8.63

TABLE xx.

COMPARISON OF AMOUNT EATEN BY WEEVILS WITH THE NUMBER OF EGGS LAID.

Week No.	No. of new eggs laid	Average No. of eggs per weevil	Average amount eaten per weevil per week in cm^2	Average Temperature $^\circ F$
1 May	35	1.17	0.195	62
2 June	89	2.97	0.758	66
3	74	2.47	1.659	70
4	61	2.03	1.521	66.5
5	12	0.40	1.164	59
6 July	1	0.03	0.780	56
7	13	0.43	0.363	56
8	89	2.97	0.423	57
9	36	1.20	0.519	60
10 August	109	3.63	0.961	65.5

Total number of eggs during ten weeks period: 519.

TEMPERATURE EFFECT

From the above table and the following graph (Fig. 36) the relationship between the number of eggs laid and the average temperatures over the ten weeks can be examined.

The optimum temperature appears to be between about 61°F and 70°F and generally more eggs were laid when the temperature was high.

Most eggs were not laid during the weeks of highest average temperatures, but in the preceding weeks, e.g:

89 eggs in week 2 at 66°F, then 70°F in week 3

89 "   " 8 at 57°F,   " 60°F   " 9

On the other hand, when the average temperature was low, the number of eggs laid was also at a minimum, e.g:

Temperature falls and number of eggs is at a minimum in

weeks 3-4, 4-5, 5-6, and both temperature and egg count

are still low in week 7.

When the temperature was rising in weeks 1 - 2, 7 - 8 and 9 - 10, the number of eggs also rose, but this did not apply in weeks 2 - 3 or 8 - 9. It may be that in week 9 the accidentally low humidity in the petri dishes accounted for the low number of eggs laid (see Factorial experiment).

Willis (1964) when writing of O. sulcatus found that the total eggs deposited during the summer did not substantially depend on the conditions under which oviposition occurred, but was related to the
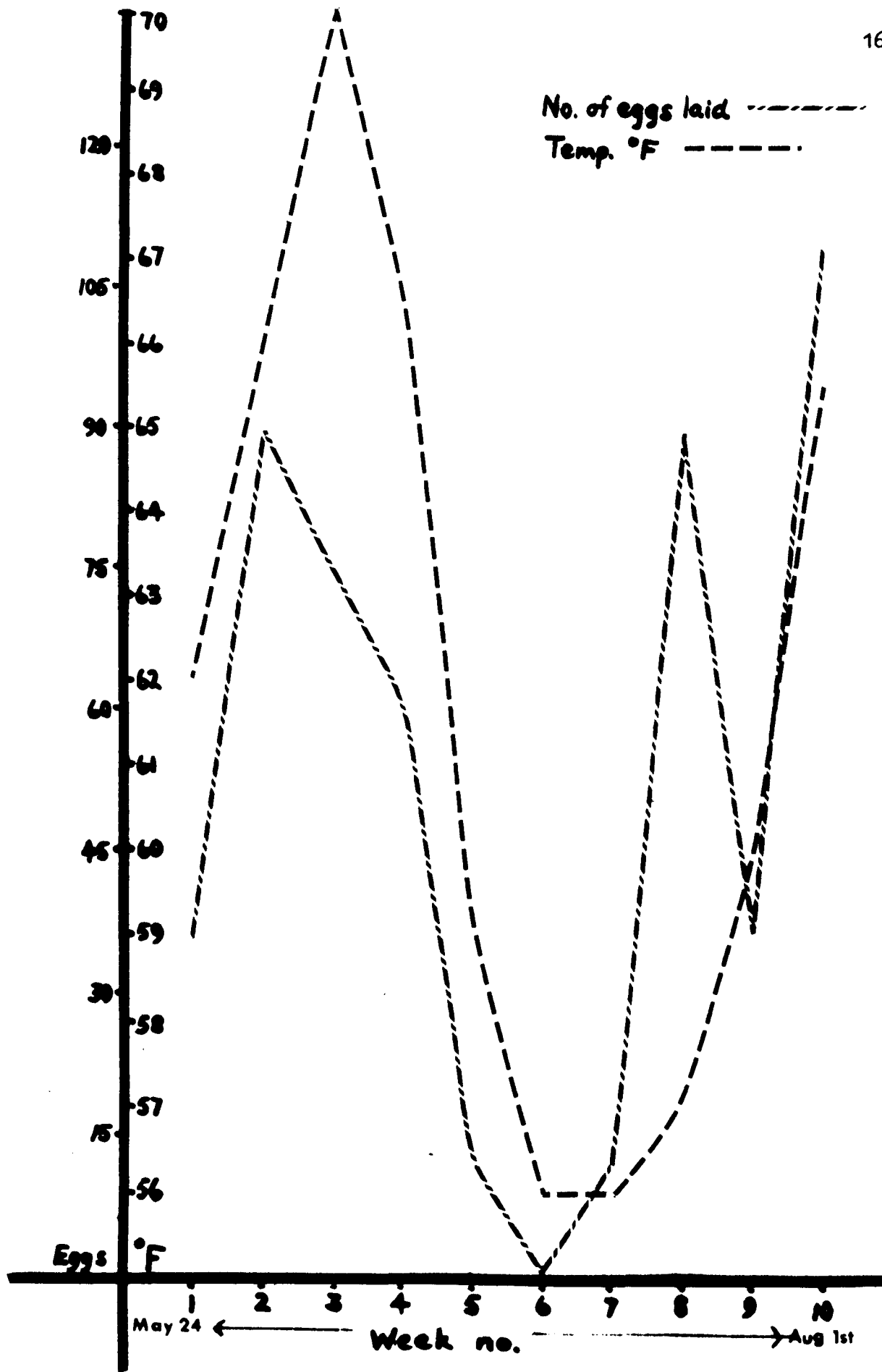
Fig. 36

life span of the weevil. At lower temperatures there was a longer

oviposition period, and therefore fewer eggs each day, but the total

count would be the same had the temperature been high.

O. singularis does not show quite the same tendencies, for although

hardly any eggs are laid in weeks 6, 7 and 8 when the temperature is

lowest, when eggs have been laid they are not in odd batches of one or

two, but in groups of 30 (weevil 23) or 19 (weevil 28). Also (weevil 15)

a very few eggs can be laid over a long period when the temperature is

high.

Jan de Wilde (1964) states that high temperatures tend to avert

induction of oviposition, but this inhibiting effect does not occur until

the temperatures are above $30^{\circ}C$ ($86^{\circ}F$). Below this, within a certain

optimum range, higher temperatures presumably encourage the laying of

eggs.

It would appear from these results that whilst generally more eggs

are laid as the normal summer temperature is rising, there must be other

factors than temperature alone (possibly humidity level and photoperiodism)

influencing the time of egg laying.

PHOTOPERIODIC EFFECT

The weevils were in a room with many windows and the dishes were

left uncovered, therefore the normal hours of light and darkness prevailed.

It cannot be said that as the days grew longer, the more eggs were laid,

but rather the opposite. Fewest eggs were laid in a week of longest days,

week 6, June 28th – July 4th.

Normally outdoors or inside in the laboratory the weevil begins to

lay eggs at the end of May – beginning of June, and I would suggest that

it is the short days of spring together with the rise of temperature which initiate oviposition. Later, it would appear from these results, temperature and not the length of day is the dominant influence on time of egg laying.

HUMIDITY EFFECT

In most weeks the humidity was kept constantly high by the application of water to the filter papers in the dishes, and the influence of a fluctuating R.H. would be disregarded.

During week 9 (19th - 25the July), when the average temperature rose to 60°F, the filter papers were accidentally allowed to dry out and the level of egg laying dropped at a time when it might have been expected to increase.

This drop in the number of eggs laid can probably be attributed to a low R.H. This relationship will be discussed further at the end of the Factorial experiment results.

NUTRITIONAL EFFECT

In Table xxi and in the following graphs, two obvious facts emerge.

Firstly, the peaks for consumption of food follow the rises in temperature (Fig. 41). One would assume that the rise in temperature brings about an increase in general metabolic rate and therefore an increase in food utilisation.

Secondly, it can clearly be seen that the peak periods for egg laying precede the peaks for feeding, as in weeks 2 and 3, and weeks 8 and 10 (Fig. 37). Feeding seems to have a direct connection with egg laying, the amount of food consumed and the timing being influenced by the numbers of eggs laid during the previous week.
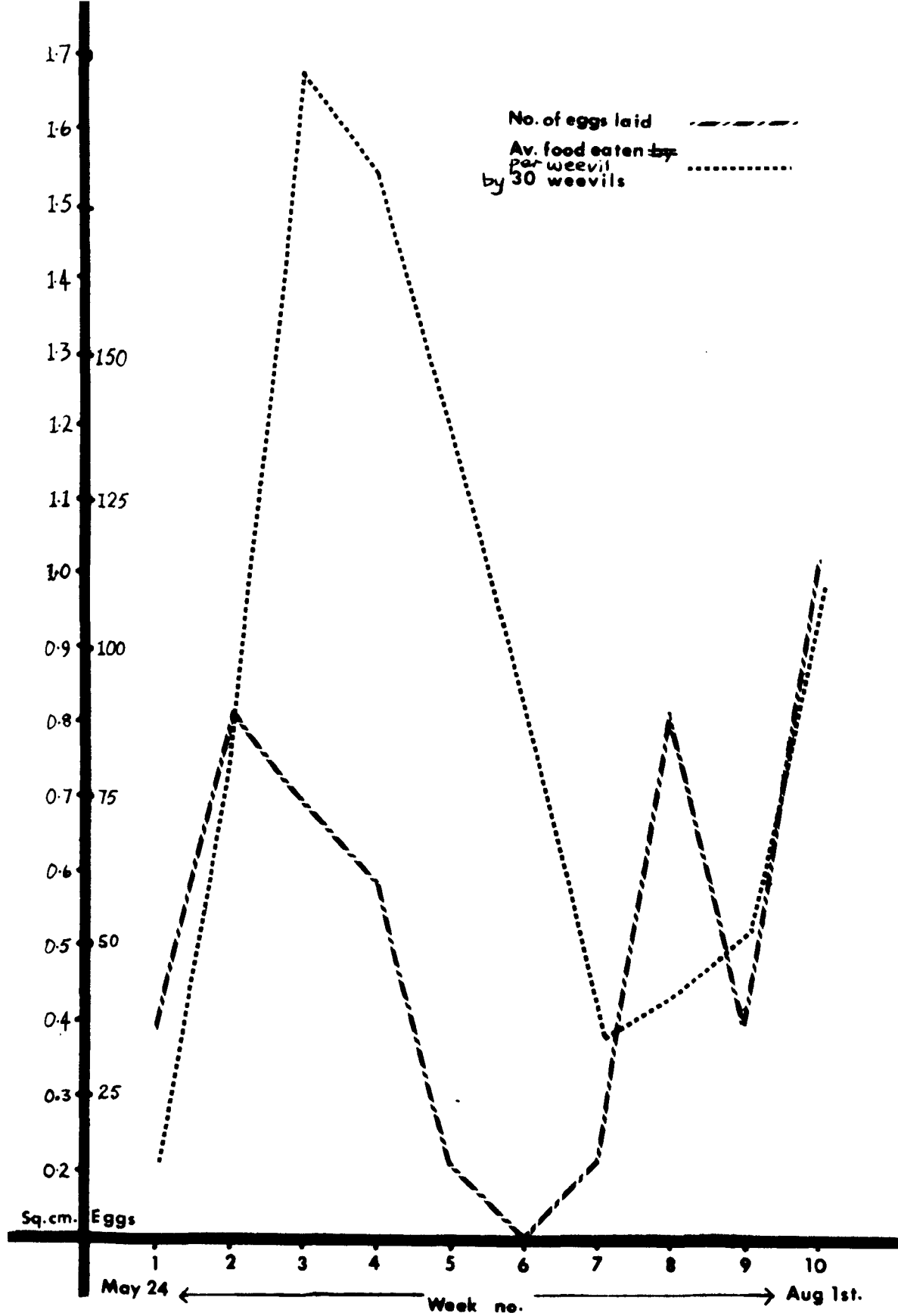
Fig. 37.

On the graphs showing the weevils fed on different types of leaf (Fig.38-40) this connection is perhaps even more easily seen, especially for those weevils numbered 1 - 10.

Gillet (1957) suggested that in mosquitoes the abdominal distention by food intake stimulated the egg laying process. I would propose that the opposite arises in O. singularis, and that because the abdomen has become so distended with eggs, eating is uncomfortable for the weevil. When eggs have been laid and the abdomen is comparitively empty, the weevil eats more food.

To show this more clearly, results from individual egg-laying weevils (but disregarding those that laid only once either in the first or last week) are shown below, Table xxii.

It can be seen from these tables that no weevil appears to eat an extra amount prior to oviposition. In fact, at the end of the Factorial experiment which follows, some of the weevils laid eggs without having eaten for 17 or 18 weeks. On the other hand, those weevils which had eaten recently laid more eggs.

According to some other workers in this field, some Coleoptera have to go through a stage of highly active feeding just before oogenesis, whilst some mosquitoes require a blood meal prior to oviposition (de Wilde 1964). Other species of mosquitoes will develop eggs without nutrition being required, and other insects need to change the balance of nutrients in their diet before oviposition (Flanders 1935). It can be concluded that insects vary considerably in their nutritional requirements prior to oogenesis and oviposition.
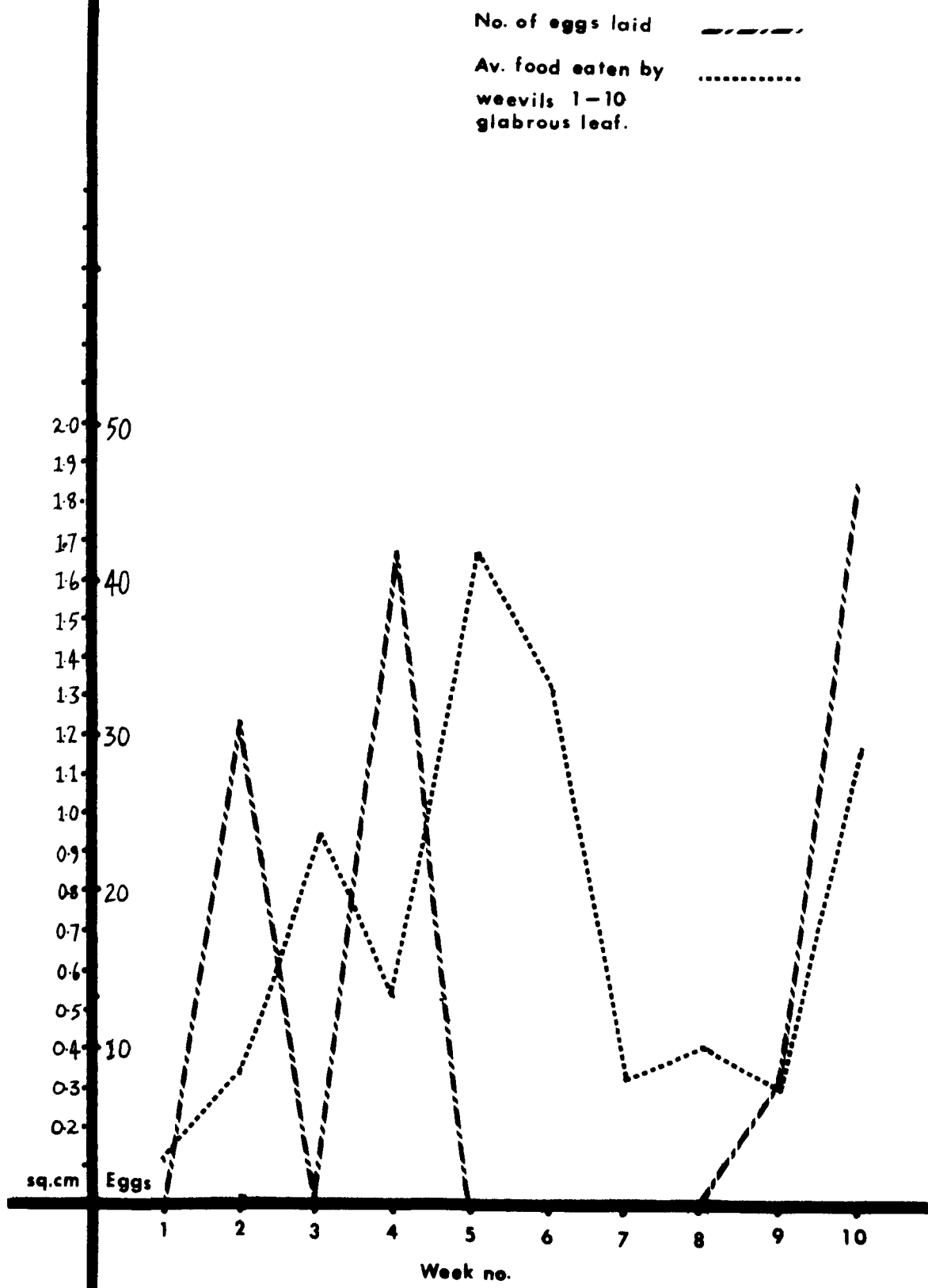
Fig. 38
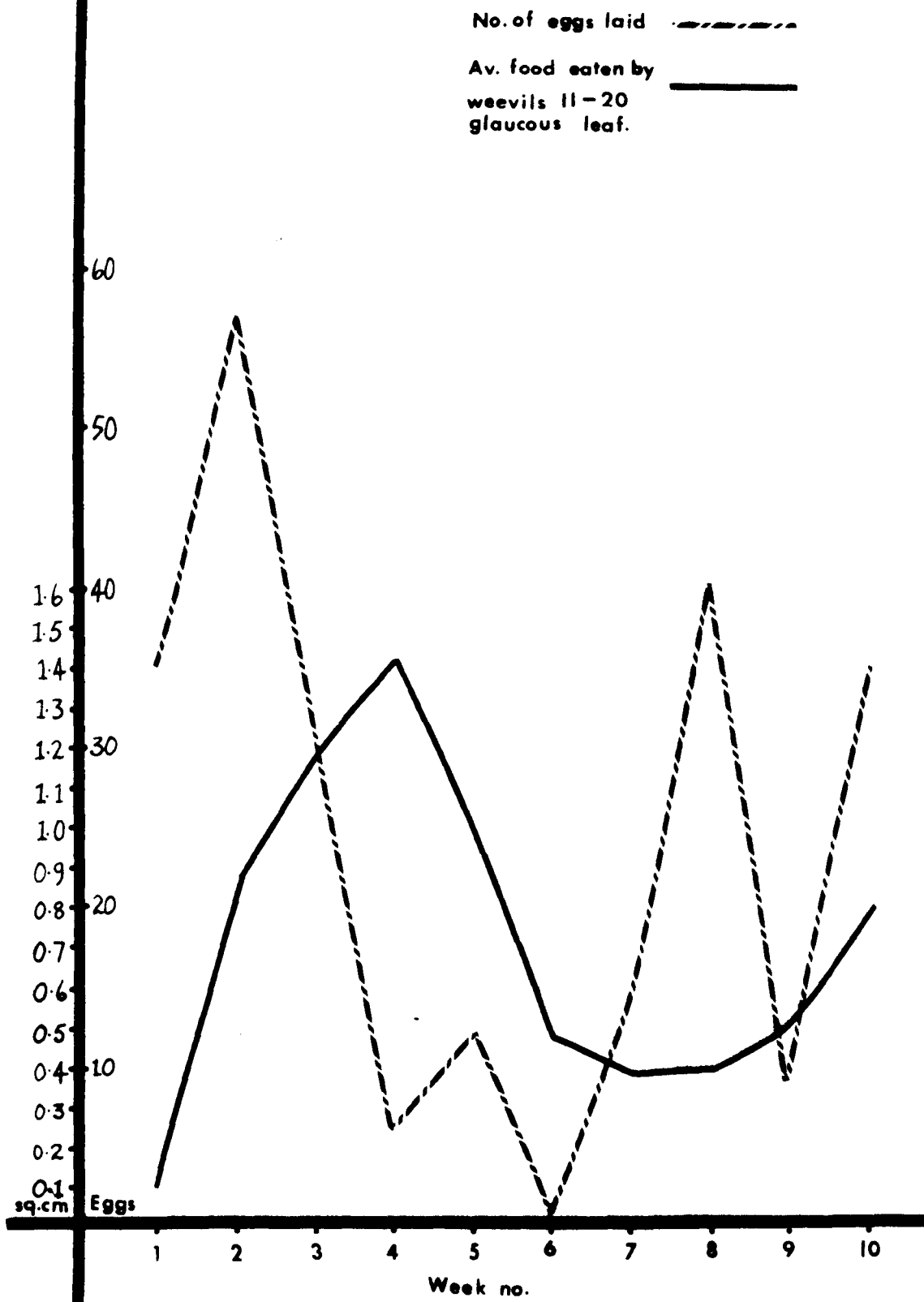
Fig. 39.
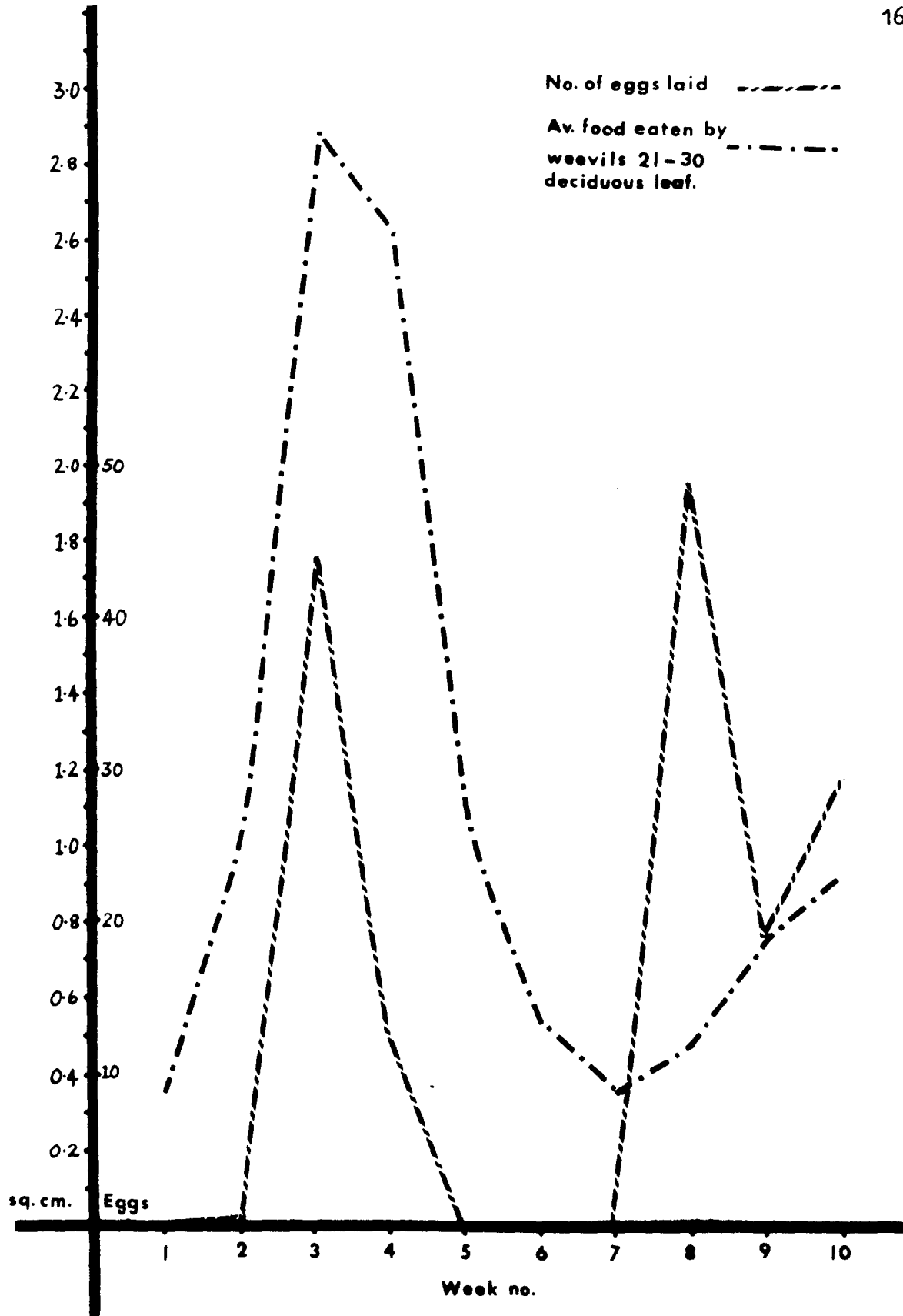
Fig. 40

O. singularis probably normally eats before egg laying, but not to any great extent. Willis (1964) states that O. sulcatus requires a certain amount of feeding prior to oviposition. This does not seem to apply to O. singularis according to my findings. More feeding seems to occur just after oviposition.

These results are then followed by data for eight non-laying weevils from the same experiment (Table   ) which have been plotted against the others on a graph.

XXiii

On this graph (Fig.41) four separate peaks can be seen between weeks 1 - 6. The first peak shows the maximum eggs laid in week 2 by the eight weevils. This is followed by the peak for the maximum temperature of $70^{o}F$ coinciding with that for food consumption by the eggless weevils in week 3.

The peak of food consumption by the laying weevils follows in week 4, two weeks after maximum oviposition.
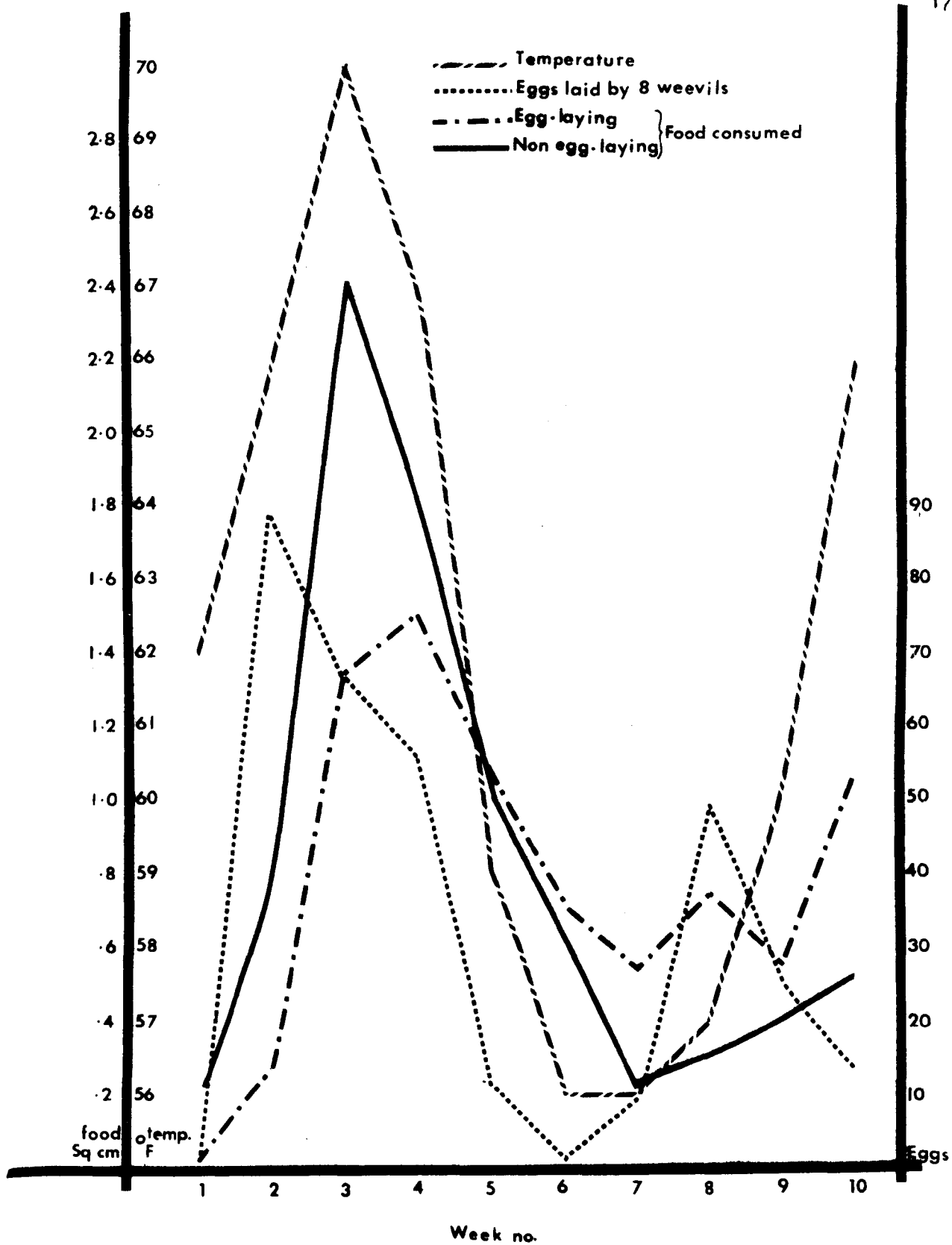
Fig. **41.**

TABLE xxi

Week	Weevil No.6		Weevil No.10		Weevil No.12		Weevil No.14	
	Eggs	Food eaten in cms.	Eggs	Food eaten	Eggs	Food eaten	Eggs	Food eaten
1	0	0	0	.235	0	0	0	0
2	31	.386	0	.052	17	.392	37	.786
3	0	2.200	0	0	19	0	0	2.021
4	0	0	41	1.455	0	1.412	0	.416
5	0	1.396	0	2.358	0	1.157	7	.064
6	0	1.387	0	1.753	0	.286	0	.156
7	0	.541	0	.786	0	0	9	.408
8	0	.588	0	.706	0	.081	0	.786
9	0	0	6	.476	0	.126	0	.614
10	0	.504	10	2.358	0	.020	0	1.572

Week	Weevil No.15		Weevil No.23		Weevil No.25		Weevil No.28	
1	1	0	0	0	0	.049	0	.014
2	3	.331	0	.175	1	.376	0	0
3	4	.181	34	3.144	10	.316	0	2.068
4	2	.576	0	3.930	13	2.358	0	1.448
5	5	1.234	0	2.954	0	.786	0	.101
6	1	.601	0	.676	0	.442	0	.248
7	0	1.047	0	.566	0	.252	0	.166
8	0	.503	30	1.572	0	.66	19	.726
9	0	0	18	1.572	0	.136	1	1.330
10	0	.146	3	2.854	0	.186	0	.701

TABLE xxii

AMOUNT EATEN WEEKLY IN CM^2 BY 8 EGG-LAYING WEEVILS

Weevil No.	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10
6	0	.386	2.200	0	1.396	1.387	.541	.558	0	.504
10	.235	.052	0	1.455	2.358	1.753	.786	.706	.476	2.358
12	0	.286	.987	1.828	.541	.561	.671	.977	.463	.236
14	0	.786	2.020	.416	.064	.156	.408	.786	.614	1.572
15	0	.331	.181	.576	1.234	.601	1.047	.503	0	.146
23	0	.175	3.144	3.930	2.954	.676	.566	1.572	1.572	2.854
25	.049	.376	.316	2.358	.786	.442	.254	.166	.136	.186
28	.014	0	2.068	1.448	.101	.248	.166	.726	1.330	.701
Total	0.298	2.392	10.916	12.011	9.434	5.824	4.439	5.994	4.591	8.557
Average	0.037	0.299	1.364	1.501	1.179	0.728	0.555	0.749	0.574	1.069

TABLE xxiii

AMOUNT EATEN WEEKLY IN CM^2 BY 8 NON-EGG LAYING WEEVILS

NO-EGG WEEVILS

Weevil No.	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10
3	0	.388	.446	1.294	1.372	1.462	.141	.171	0	1.022
7	.557	.392	2.200	.066	1.517	1.357	.326	.786	.962	1.232
11	0	.392	0	1.412	1.157	.286	0	.081	.026	.021
21	1.350	2.626	4.686	2.990	.552	.786	.236	.336	1.362	.261
22	.005	.969	4.676	2.216	1.347	.256	.111	.031	.106	.786
26	0	.293	2.131	3.012	.506	.374	.209	.173	0	.026
27	0	.376	2.859	1.387	.336	.131	.546	.441	.365	.411
30	0	.635	2.203	2.230	1.352	.731	.336	.381	.441	.271
Total	1.912	6.071	19.201	14.607	8.139	5.383	1.905	2.400	3.262	4.030
Average	0.239	0.759	2.400	1.826	1.017	0.673	0.238	0.300	0.408	0.504

Type of leaf eaten

The total numbers of eggs laid by weevils fed on each type of food is:

Glabrous	Glaucous	Deciduous
127	237	155

whereas more of the deciduous leaf was eaten, followed by the glabrous, than the glaucous types. This dispels any theory that with O. singularis the number of eggs laid is related to the amount of food eaten. The weevils here which ate less laid the most eggs. It may be that the woolly texture on the back of the glaucous leaves was some encouragement to egg laying. In those cases the weevil laid eggs actually on the lower surface of the leaf while eggs were laid on the surface of the petri dish where the other two types of leaves were provided.

These results also tend to support the view that when the abdomen is particularly distended with eggs, there is less room for food.

CONCLUSIONS

Amongst the factors influencing egg laying in O. singularis, temperature and probably relative humidity are of prime importance. The state of the abdomen, whether full of eggs or relatively empty, has an effect on the time and amount of feeding. The amount of food eaten before egg laying does not appear to influence the numbers of eggs laid.

FACTORIAL EXPERIMENT

The following experiment was set up in the laboratory in June 1964 in order to discover the effects upon the Clay-coloured Weevil (Otiorhynchus singularis L.) of varying the factors, each at two levels:

> Light,
>
> Temperature,
>
> Humidity,
>
> Food supply,

in relation to:

> + (a)   Number of eggs laid,
>
> + (b)   Time of laying,
>
> (c)   Longevity of parent weevils,
>
> (d)   Amount of food eaten,
>
> (e)   Feeding habits.

All the weevils used had been caught on R. ponticum at night at Keele during early June 1964, and none had so far laid eggs in captivity.   All were fed, up to the day on which the experiment began, and were selected at random for each treatment.   Those dying were replaced by others.

+   These results were not available during the first ten weeks.

FACTORIAL EXPERIMENT EQUIPMENT
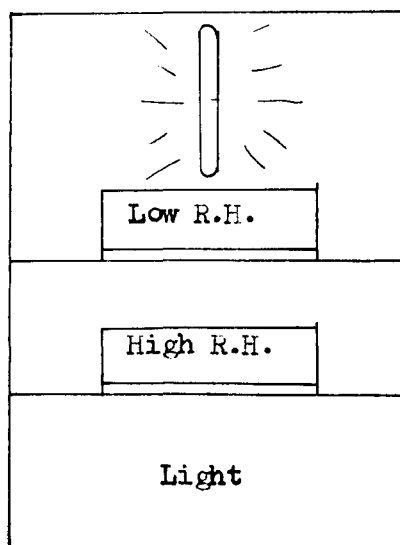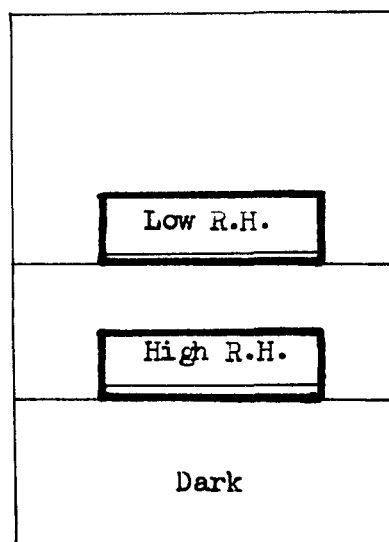
Refrigerator "A"   Refrigerator "B"
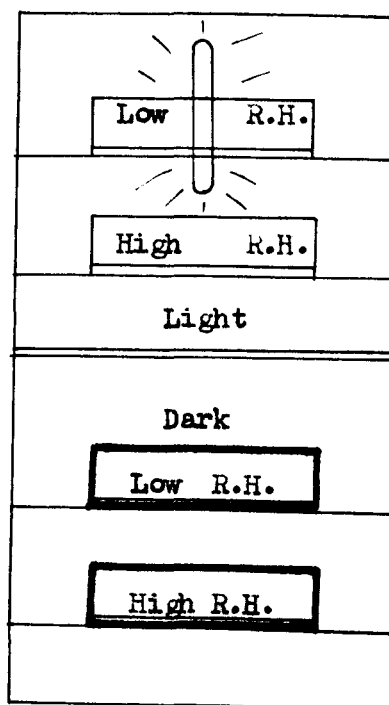
Incubator

Fig 42.

TABLE xxiv   FACTORIAL EXPERIMENT

Four variable factors
at two levels:

	T	H	L	F
1	●	●	●	●
2	●	●	●	
3	●	●		●
4	●	●		
5	●		●	●
6	●		●	
7	●			●
8	●			
9		●	●	●
10		●	●	
11		●		●
12		●		
13			●	●
14			●	
15				●
16				

Temp.   ● High   Low

Humidity   ● High   Low

Food   ● +   no

Light   ● +   no

A typically marked
petri dish

⑨

△2

10 replicate sets numbered   △1   to   △10

with 16 treatments in each set marked   ①   to   ⑯

2 sets of 10 per plastic box.

FACTORIAL EXPERIMENT:

APPARATUS USED

Two household refrigerators were used, one of which was fitted with a small fluorescent strip light, lit continuously, the other left dark. Both refrigerators were set to maintain a steady temperature of 6° C.

To obtain a higher temperature, an incubator was set at 18°C. At the top of the incubator a small light, similar to that in the refrigerator, was inserted. In order to provide darkness in the lower half of the incubator, the dishes used to house the weevils were placed in boxes constructed of black plastic material, whilst all other boxes were made of transparent plastic (see Fig.43).

The weevils were placed separately in plastic petri-dishes which had several holes punched in the lid to allow entry of air and to stabilise the humidity. The boxes were labelled using coloured, round dots to denote the different treatments as in Table xxiv.

Sixteen different treatments were given and each treatment replicated ten times, involving 160 weevils altogether. Plastic boxes were made to accommodate 20 dishes or two sets of treatments, therefore eight boxes were used, six transparent and two opaque. The boxes measured 12" x 9" x 4". Half an inch from the base of the box, inside, was fitted a small ledge on to which was placed a sheet of open aluminium mesh. This allowed light through the mesh where needed and also provided a stable base for the petri-dishes.
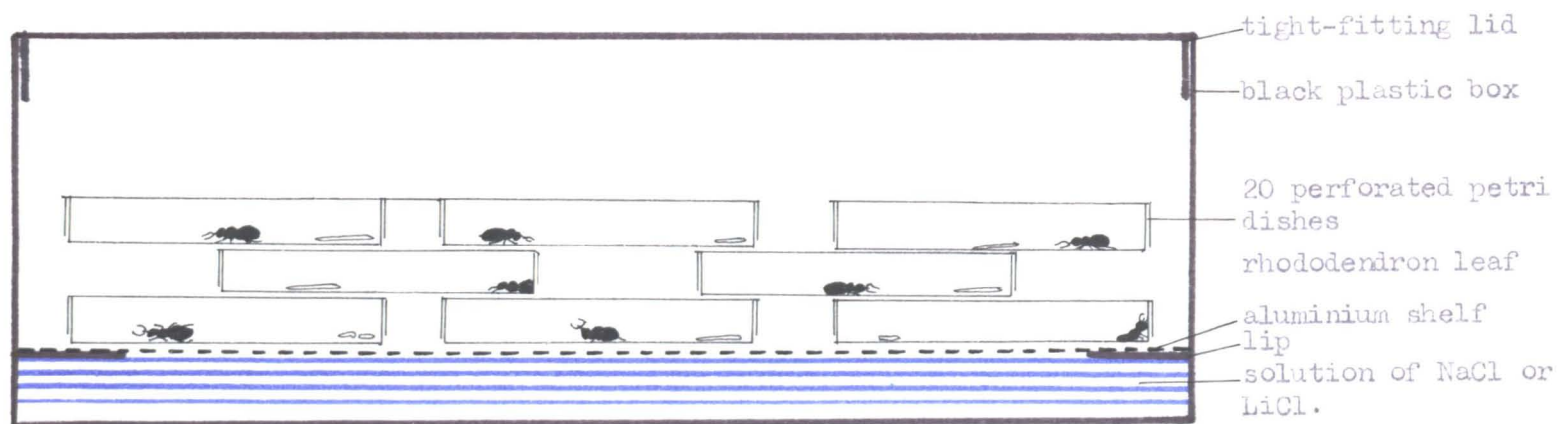
Cross section of one of the plastic boxes used
in the Factorial Experiment.

Fig 43.

APPARATUS FOR CUTTING OUT LEAF SEGMENTS

strong spring

metal clamp on
stand

cork borer,
diameter 1 cm.

rhododendron leaf

wooden base

Uniform holes
1 cm. diameter
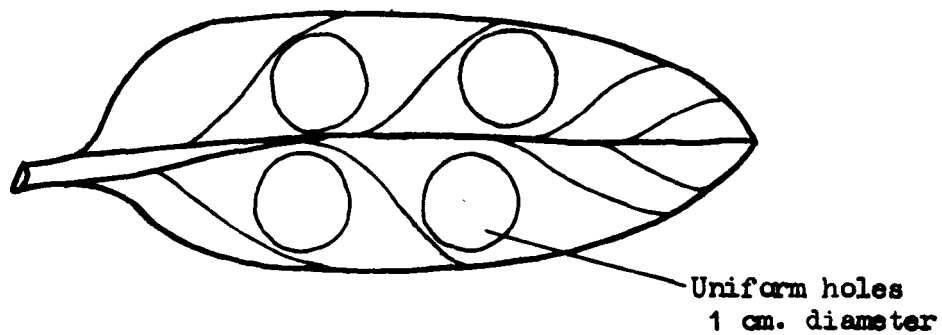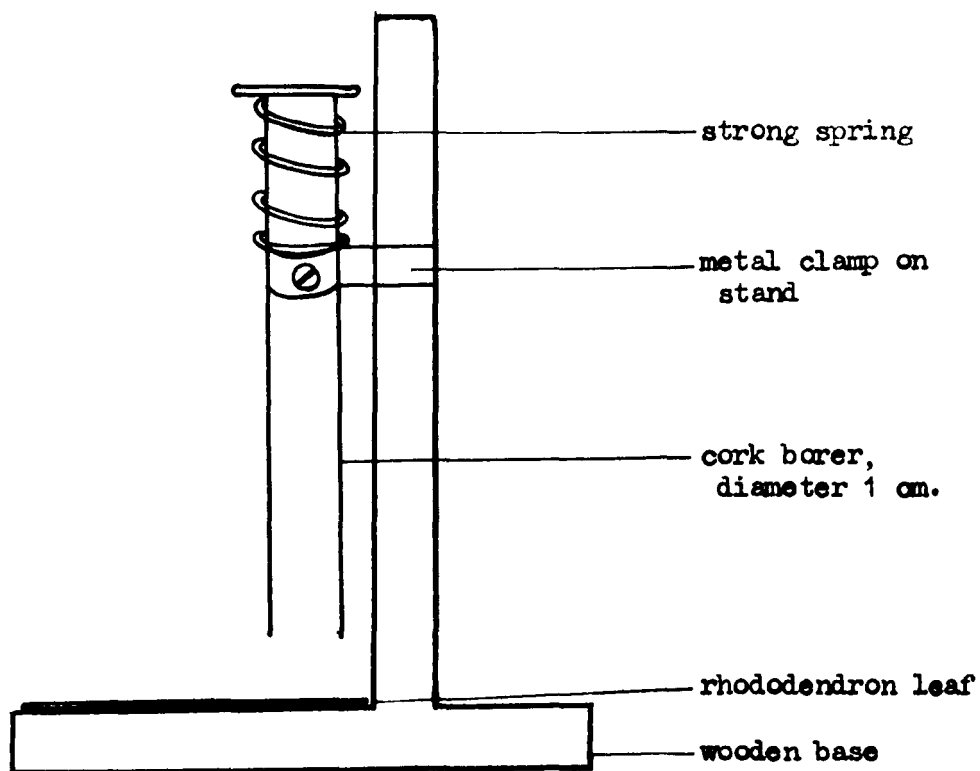
Rhododendron leaf

Fig 44.

Under the mesh was placed the liquid to provide a stable high or low humidity.

260 gm. NaCl. or anhydous 350 gm. LiCl. were dissolved in 500 ml. water. In each case a saturated solution was obtained with some crystals left in the solution. This provided the boxes with humidities of 75% R.H. and 12% R.H. respectively, and these were tested periodically with the Cobalt Thiocynate paper and the Lovibond Comparator, and the Wet and Dry Bulb Hygrometer. Four boxes contained NaCl and four, LiCl. The humidities varied later.

Half the weevils in the experiment were fed regularly on smooth R. ponticum leaf, the others received no food. Those fed received circles of leaf 1 cm. in diameter once every seven days, or whenever the food had been eaten if this time was less than seven days. The circles of leaf were taken from the centre of the leaf, intervenously, using neither midrib nor the leaf margin. They were cut out by a small machine made in the laboratory by fixing a metal cork-borer on to a stand with a wooden base and attaching a spring above the borer. The cutting edge of the metal was exactly 1 cm. in diameter and was sharpened regularly by filing (see Fig.44). The leaves used were all of similar texture, i.e. not the young, flexible, light-coloured new leaves, nor the tough, dark-green leaves of two or more years.

At each reading the circles of leaf were taken out of the dish and placed on to transparent, adhesive tape. Another

piece of tape was placed over the top of the leaf pieces.   They were

then labelled in ink.
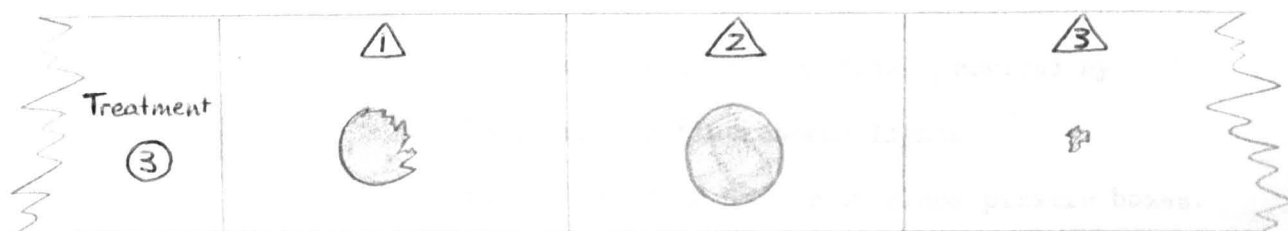
The tape could be cut and prepared just before each

count.

These were then magnified x 10 by using a modified micro-

projector and the outline carefully drawn on to prepared sheets of

paper.   These could be kept until time was available for measure-

ments.   The areas were measured by a planimeter and recorded in tables.
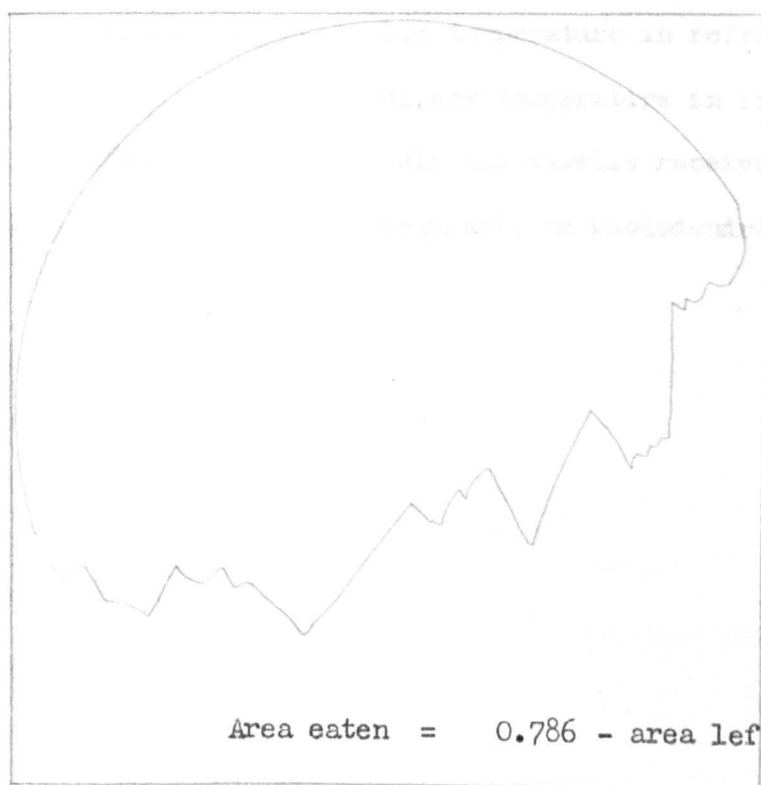
Magnified outline

x 10 original

Area eaten = 0.786 - area left in cm^2

SUMMARY

LIGHT: Continuous light on four boxes provided by

        Atlas, tubular fluorescent lights.

        Darkness provided by use of black plastic boxes.

HUMIDITY: Low R.H. of 12% using sat. LiCl solution.

        (This later rose to 27% and then to 40%).

        High R.H. of 75% using sat. NaCl solution.

        Solution in base of each box.

        (After 10 weeks the humidity was raised to

        100% by using water on the filter-paper in

        petri-dishes).

TEMPERATURE: Low temperature in refrigerators 6°C.

        Higher temperature in incubator 18°C.

FOOD: Half the weevils received no food, others fed

        regularly on rhododendron leaf.

Readings recorded were:

        (a) Weevil dead or alive

        (b) Number of eggs laid

        (c) Amount of food eaten

All readings were taken in the morning, 3 times per week, on Monday, Wednesday and Friday.

RESULTS OF FACTORIAL EXPERIMENT

FIRST TEN WEEKS:

Probably because of the highest humidity being only 75% R.H. the weevils did not lay any eggs during the first 10 weeks, although most of them had eggs internally when dissected after death.

The results can only show the effects of the various treatments on longevity of the adult weevils, and on the feeding habits.

i. Effects of factors on longevity:

The following statistical data for the first ten weeks were obtained as shown.

At first, results were calculated with actual percentage weevils dead each week, but this did not take into account that some died early in the week, others at the end.

Counts of weevils dead and replaced were made each Monday, Wednesday and Friday, each week beginning on a Friday.

New weevils were only added on Fridays and allowance was made for this as below:-

Fri.	Sat.	Sun.	Mon.	Tues.	Wed.	Th.	Fri.
			x		x		x
		Counts	1		2		3

By Friday, count 1 have been dead $4 + \overset{Av.}{1\tfrac{1}{2}} = 5\tfrac{1}{2}$ days

<div align="center">

2 " " $2 + 1 = 3$ "

3 " " $1 = 1$ "

</div>

and the results have been weighted accordingly, those in count

<div align="center">

1 x $5\tfrac{1}{2}$

2 x 3

3 x 1

</div>

Ten weevils were in each treatment $\therefore$ the final

percentage of dead each week $= \dfrac{x \ (5\tfrac{1}{2} + 3 + 1) \ 100}{95}$ %

The first 10 weeks results, shown on the following page, were used for the calculations, using the average % of 10 weeks for the different 16 treatments.

TABLE xxv

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Treatment no.
26.2	23.2	24.8	23.4	43.3	44.7	45.9	47.2	8.5	16.0	12.5	17.2	29.0	28.0	26.8	27.6	Average % dead

T_1 High								T_2 Low								
High H_1				Low H_2				High H_1				Low H_2				
L_1		L_2		L_1		L_2		L_1		L_2		L_1		L_2		
F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	
26.2	23.2	24.8	23.4	43.3	44.7	45.9	47.2	8.5	16.0	12.5	17.2	29.0	28.0	26.8	27.6	% dead av. of 10 wk.

TABLE xxvi

Summing over T:-

H_1 High				H_2 Low			
L_1		L_2		L_1		L_2	
F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2
34.7	39.2	37.3	40.6	72.3	72.7	72.7	74.8

Summing over H:-

T_1 High				T_2 Low			
L_1		L_2		L_1		L_2	
F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2
69.5	67.9	70.7	70.6	37.5	44.0	39.3	44.8

Summing over F:-

L_1 Light				L_2 Dark			
T_1		T_2		T_1		T_2	
H_1	H_2	H_1	H_2	H_1	H_2	H_1	H_2
49.4	88.0	24.5	57.0	48.2	93.1	29.7	54.4

Summing over L:-

F_1				F_2			
T_1		T_2		T_1		T_2	
H_1	H_2	H_1	H_2	H_1	H_2	H_1	H_2
51.0	89.2	21.0	55.8	46.6	91.9	33.2	55.6

TABLE xxvii

SUMMING OVER VARIABLES TWO AT A TIME:-

L and H

	L_1	L_2	
H_1	73.9	77.9	151.8
H_2	145.0	147.5	292.5
	218.9	225.4	444.3

F and H

	F_1	F_2	
H_1	72.0	79.8	151.8
H_2	145.0	147.5	292.5
	217.0	227.3	444.3

L and T

	L_1	L_2	
T_1	137.4	141.3	278.7
T_2	81.5	84.1	165.6
			444.3

F and T

	F_1	F_2	
T_1	140.2	138.5	278.7
T_2	76.8	88.8	165.6
			444.3

H and T

	H_1	H_2	
T_1	97.6	181.1	278.7
T_2	54.2	111.4	165.6
			444.3

F and L

	F_1	F_2	
L_1	107.0	111.9	218.9
L_2	110.0	115.4	225.4
			444.3

Grand Total = 444.3

TO FIND CORRECTING FACTOR:

$$\frac{\text{Square of Grand Total}}{\text{Total no. of observations}} \quad = \quad \frac{444.3^2}{16}$$

$$= \quad \frac{197402.5}{16}$$

$$= \quad 12337.6556$$

$$= \quad 12337.7$$

TO FIND THE MAIN EFFECTS OF SEPARATE FACTORS:

Square factor totals, sum these squares.

Divide number by individuals forming each total (8)

Subtract the correcting factor:-

MAIN EFFECT OF FACTOR T:

$$\frac{(T_1^2 + T_2^2)}{8} - \frac{444.3^2}{16} = \text{main effect.}$$

$$\frac{(178.7^2 + 165.6^2)}{8} - \text{c.f.}$$

$$\frac{77673.7 + 27423.4}{8} - \text{c.f.}$$

$$\frac{105097.1}{8} - \text{c.f.} = 13137.1 - 12337.7 = \underline{799.4} \qquad \text{T}$$

MAIN EFFECT OF FACTOR F:

$$\frac{(F_1^2 + F_2^2)}{8} - \text{c.f.}$$

$$\frac{(217^2 + 227.3^2)}{8} - \text{c.f.}$$

$$\frac{(17089.0 + 51665.3)}{8} - \text{c.f.}$$

$$\frac{98754.3}{8} - \text{c.f.} = 12344.3 - 12337.7 = \underline{6.6} \qquad \text{F}$$

MAIN EFFECT OF FACTOR H:

$$\frac{(H_1{}^2 + H_2{}^2)}{8} \; - \; \text{c.f.}$$

$$\frac{(151.8^2 + 292.5^2)}{8} \; - \; \text{c.f.}$$

$$\frac{(23043.2 + 85556.3)}{8} \; - \; \text{c.f.}$$

$$\frac{108599.5}{8} \; - \; \text{c.f.} \; = \; 13574.9 - 12337.7 = \underline{1237.2} \qquad \qquad \text{H}$$

MAIN EFFECT OF FACTOR L:

$$\frac{(L_1{}^2 + L_2{}^2)}{8} \; - \; \text{c.f.}$$

$$\frac{(218.9^2 + 225.4^2)}{8} \; - \; \text{c.f.}$$

$$\frac{47917.2 + 50805.2}{8} \; - \; \text{c.f.}$$

$$\frac{98722.4}{8} \; - \; \text{c.f.} \; = \; 12340.2 - 12337.7 = \underline{2.5} \qquad \qquad \text{L}$$

FIRST ORDER INTERACTIONS

From tables on p. 199 for T x L

$$\frac{(L_1 + T_1)^2 + (L_2 + T_1)^2 + (L_1 + T_2)^2 + (L_2 + T_2)^2}{4 \text{ (no. of individuals)}} \qquad - c.f. - T - L = (T \times L)$$

$$\frac{137.4^2 + 141.3^2 + 81.5^2 + 84.1^2}{4}$$

$$\frac{18878.76 + 19965.7 + 6642.3 + 7072.8}{4}$$

$$\frac{5255.65}{4} = 13139.9 - 12337.7 - 799.4 - 2.5 \qquad\qquad = \underline{0.30} \quad (T \times L)$$

H x L

$$\frac{(73.9^2 + 77.9^2 + 145.0^2 + 147.5^2)}{4}$$

$$\frac{(5461.21 + 21025.0 + 21756.25)}{4}$$

$$\frac{54310.87}{4} = 13577.718 - 12337.7 - 1237.2 - 2.5 \qquad\qquad = .318 \quad (H \times L)$$

FIRST ORDER INTERACTIONS

F x L

$$\frac{(107.0^2 + 111.9^2 + 110.0^2 + 115.4^2)}{4}$$

$$\frac{(11449.0 + 12521.61 + 12100.0 + 13317.6)}{4}$$

$$\frac{49387.77}{4} = 12346.94 - 12337.7 - 6.6 - 2.5 \qquad = \underline{0.142} \qquad (F \times L)$$

H x T

$$\frac{(97.6^2 + 181.1^2 + 54.2^2 + 111.4^2)}{4}$$

$$\frac{(9525.76 + 32797.21 + 2937.64 + 12409.96)}{4}$$

$$\frac{57670.57}{4} = 14417.64 - 12337.7 - 1237.2 - 799.4 \qquad = \underline{43.34} \qquad (H \times T)$$

FIRST ORDER INTERACTIONS

H x F

$$\frac{(72.0^2 + 79.8^2 + 145.0^2 + 147.5^2)}{4}$$

$$\frac{(5184.0 + 6368.04 + 21025.0 + 21756.25)}{4}$$

$$\frac{54333.29}{4} = 13583.32 - 12337.7 - 1237.2 - 6.6 \qquad = \underline{\underline{1.8}} \qquad (\text{H x F})$$

T x F

$$\frac{(140.2^2 + 138.5^2 + 76.8^2 + 88.8^2)}{4}$$

$$\frac{(19656.04 + 19182.25 + 5898.24 + 7885.44)}{4}$$

$$\frac{52621.97}{4} = 13155.49 - 12337.7 - 799.4 - 6.6 \qquad = \underline{\underline{11.79}} \qquad (\text{T x F})$$

TABLE xxviii

SECOND ORDER INTERACTIONS

Make out two tables using factors involved, e.g. F x H x L.

<div style="display:flex">

Table I

	H_1	H_2	
F_1			
L_1	a	b	a + b
L_2	c	d	c + d
$\nleq$	a + c	b + d	

Table II

	H_1	H_2	
F_2			
L_1	a	b	a + b
L_2	c	d	c + d
$\nleq$	a + c	b + d	

</div>

Calculate for Table I

Between cells $= \dfrac{a^2 + b^2 + c^2 + d^2}{2} - \dfrac{\boxed{\text{Totals}}^2}{8}$

Rows $\dfrac{(a \times b)^2 + (c + d)^2}{4} - \dfrac{\boxed{}^2}{8}$

Columns $\dfrac{(a \times c)^2 + (b + d)^2}{4} - \boxed{}^2$

Then: $F_1 (L \times H) = $ Between cells - Rows - Columns

and $F_2 (L \times H) = \quad$ " $\quad - \quad$ " $\quad - \quad$ " $\quad$ (using Table II)

Then $\nleq F (L \times H) = F_1 (L \times H) + F_2 (L \times H)$

$\underline{\underline{F \times L \times H}} = \nleq F (L \times H) - L \times H.$

TABLE ixxx

SECOND ORDER INTERACTIONS: - F x L x H

Table I

F_1			
	L_1	L_2	
H_1	34.7	37.3	72.0
H_2	72.3	72.7	145.0
	107.0	110.0	217.0

Table II

F_2			
	L_1	L_2	
H_1	39.2	40.6	79.8
H_2	72.7	74.8	147.5
	111.9	115.4	227.3

Calculating for Table I:-

Cells = 6553.8 - 5886.1 = 667.7

Rows = 6552.2 - 5886.1 = 666.1

Cols. = 5887.2 - 5886.1 = 1.1

$\therefore$ F_1(L x H)   0.5

For Table II:-

Cells = 7032.5 - 6458.1 = 574.4

Rows = 7031.0 - 6458.1 = 572.9

Cols. = 6459.6 - 6458.1 = 1.5

$\therefore$ F_2(L x H)   0.0

$\therefore$ F(L x H) = 0.5 + 0   = 0.5

F x L x H = 0.5 - .32   = <u>0.18</u>

TABLE xxx

SECOND ORDER INTERACTIONS:- T x L x H

Table I

	H_1	H_2	
L_1	49.4	88.0	137.4
L_1	48.2	93.1	141.3
	97.6	181.1	278.7

T_1

Table II

	H_1	H_2	
L_1	24.5	57.0	81.5
L_2	29.7	54.4	84.1
	54.2	111.4	165.6

T_2

Calculating for Table I:-

Cells = 10587.5 - 9709.2 = 878.3

Rows = 1.8

Cols. = 871.5

$\therefore T_1 \ (L \times H) = 5.0$

Calculating for Table II:-

Cells = 3845.2 - 3427.9 - 417.3

Rows = .8

Cols. = 408.9

$\therefore T_2 \ (L \times H) = 7.6$

$\therefore \quad T \ (L \times H) = 5 + 7.6 = 12.6$

$T \times L \times H = 12.6 - .32 = \underline{12.28}$

TABLE xxxi

SECOND ORDER INTERACTIONS:- T x H x F

Table I

T_1			
	H_1	H_2	
F_1	51.0	89.2	140.2
F_2	46.6	91.9	138.5
	97.6	181.1	278.7

Table II

T_2			
	H_1	H_2	
F_1	21.0	55.8	76.8
F_2	33.2	55.6	88.8
	54.2	111.4	165.6

Calculating for Table I:-

Cells = 10587.3 - 9709.2 = 878.1

Rows =   .3

Cols. = 10580.7 - 9709.2 = <u>871.5</u>

$\therefore$ $T_1(H \times F)$ = 6.3

For Table II:-

Cells = 3874.0 - 3427.9 = 446.1

Rows =   18.0

Cols. = 3836.8 - 3427.9 = <u>408.9</u>

$\therefore$ $T_2(H \times F)$ = 19.2

$\therefore$ T (H x F) = 6.3 + 19.2   = 25.5

T X H X F = 25.5 - 1.82   = <u>23.68</u>

TABLE xxxii

<u>SECOND ORDER INTERACTIONS</u>:- T x L x F

Table I

	T_1		
	L_1	L_2	
F_1	69.5	70.7	140.2
F_1	67.9	70.6	188.5
	137.4	141.3	278.7

Table II

	T_2		
	L_1	L_2	
F_1	37.5	39.3	76.8
F_2	44.0	44.8	88.0
	81.5	84.1	165.0

Calculating for Table I:-

Cells = 9711.6 - 9709.2 = 2.4

Rows = 9709.5 - 9709.2 = .3

Cols. = 9711.0 - 9709.2 = 1.8

$\therefore T_1 (L \times F)$ = 0.3

For Table II:-

Cells = 3446.8 - 3427.9 = 18.9

Rows = 3445.9 - 3427.9 = 18.0

Cols. = 3428.7 - 3427.9 = .8

$\therefore T_2 (L \times F)$ = 0.1

$\therefore$ T (L x F) = .3 + .1   =   .4

T x L x F = 0.4 - .32 =   .08

TABLE xxxiii

	Sum of (s.s.) squares	d.f.	
T	799.4	1	Residual = Total sum of squares
H	1237.2	1	- c.f.
L	2.5	1	- sums of squares
F	6.6	1	= 14479.6
T x L	0.3	1	- 12337.7
H x L	0.32	1	2141.9
F x L	0.14	1	- 2139.6
H x T	43.34	1	2.3
H x F	1.82	1	
T x F	11.79	1	
T x L x F	0.08	1	
T x H x F	23.68	1	
T x H x L	12.28	1	
F x H x L	0.18	1	
	2139.6		
T x L x H x F	2.3	1 = R	
		15	

Mean square = $\dfrac{\text{s.s.}}{\text{d.f.}}$

∴ same figure as s.s. column

$F = \dfrac{\text{mean square}}{2.3\ (R)}$

TABLE xxxiv

	Mean Sq. (m.s.)	F	Significant at 0.5%
T	799.4	347.5	✓
H	1237.2	537.9	✓
L	2.5	1.1	
F	6.6	2.86	
T x L	0.3	1<	
H x L	0.32	1<	
F x L	0.14	1<	
H x T	43.34	18.82	✗
H x F	1.82	1<	
T x F	11.79	5.13	✗
T x L x F	.08	1<	
T x H x F	23.68	10.30	✗
T x H x L	12.28	5.34	✗
F x H x L	0.18	1<	
Residual (R)	2.3		

From the figures on the preceding page we can see that only the factors T and H are significant at 1 : 1 on the F tables. These two factors have such a great effect that any others are masked. Light and food have no significant effect on longevity.

Some of the interactions, marked x, although not significant, have some slight effect and their further effects are shown on the following pages.

TO FIND THE EFFECTS OF SIGNIFICANT FACTORS AND THOSE HAVING ONLY A SMALL EFFECT.

Grand mean (G) = $\frac{\text{Total}}{16}$ = 27.77 or 27.8.

Main effects   n = 8

1.	T.	Observations		Effects
		T_1	34.8 (Av. of all T_1)	+ 7.0
		T_2	20.7 (Av. of all T_2)	- 7.0

Effect of T_1 relative to G is 34.8 - 27.8   = + 7.0

Effect of T_2 relative to G is 20.7 - 27.8   = - 7.0

2.	H.	H_1	19.0	- 8.8
		H_2	36.6	+ 8.8

3.	F.	F_1	27.12	- 0.65
		F_2	28.41	+ 0.65

Effect of F_1 relative to G is 27.12 - 27.77 = -0.65

Effect of F_2 relative to G is 28.42 - 27.77 = + 0.65

The effects of T and H relative to G are large, whilst F is very small and insignificant.

TWO FACTOR INTERACTION EFFECTS

T x H   n = 4

Mean values:

	H_1	H_2
T_1	24.4	45.3
T_2	13.6	27.9

(a)

Effects relative to G after accounting for main effects:

	H_1	H_2
T_1	− 1.6	+ 1.7
T_2	+ 1.6	− 1.7

(b)

Mean $(H_1 T_1)$ = 24.4 = $G + H_1 + T_1 + H_1 T_1 + \epsilon$

$\qquad\qquad$ = 27.8 − 8.8 + 7 + $H_1 T_1 + \epsilon$

$\qquad H_1 T_1$ = 24.4 − 27.8 + 8.8 − 7 = − 1.6

Mean $(H_2 T_1)$ = 45.3 = $G + H_2 + T_1 + H_2 T_1 + \epsilon$

$\qquad\qquad$ = 27.8 + 8.8 + 7 + $H_2 T_1 + \epsilon$

$\qquad H_2 T_1$ = 45.3 − 27.8 − 8.8 − 7 = + 1.7

Mean $(H_1 T_2)$ = 13.6 = $G + H_1 + T_2 + H_1 T_2 + \epsilon$

$\qquad\qquad$ = 27.8 − 8.8 − 7 + $H_1 T_2 + \epsilon$

$\qquad H_1 T_2$ = 13.6 − 27.8 + 8.8 + 7 = + 1.6

Mean $(H_2 T_2)$ = 27.9 = $G + H_2 + T_2 + H_2 T_2 + \epsilon$

$\qquad\qquad$ = 27.8 + 8.8 − 7 + $H_2 T_2 + \epsilon$

$\qquad H_2 T_2$ = 27.9 − 27.8 − 8.8 + 7 = − 1.7

Using the mean values (a) the following graph can be drawn:
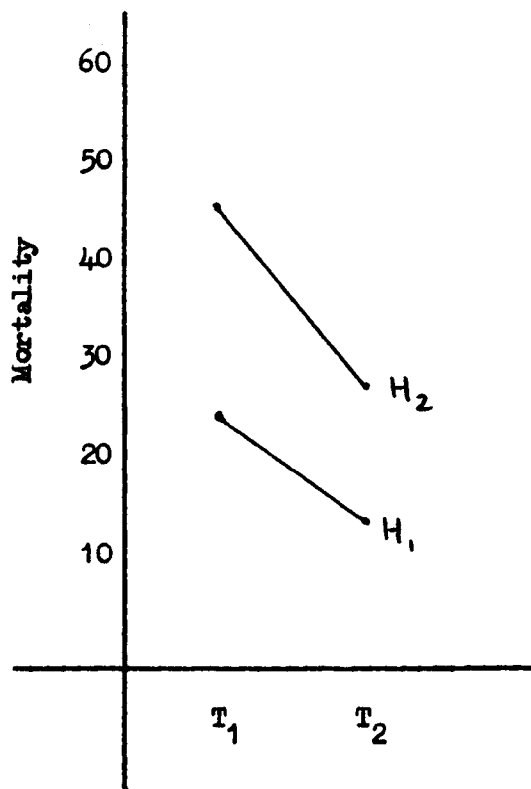
Because the lines are not parallel we can conclude that there is some interaction effect between T and H. It can be seen that at a high temperature T_1, there is greater mortality at a lower humidity H_2 than at H_1. There is more significant interaction between the two at high temperature than at low.

When the factors H and T and their separate effects are eliminated (b), the effects relative to G can be plotted thus:
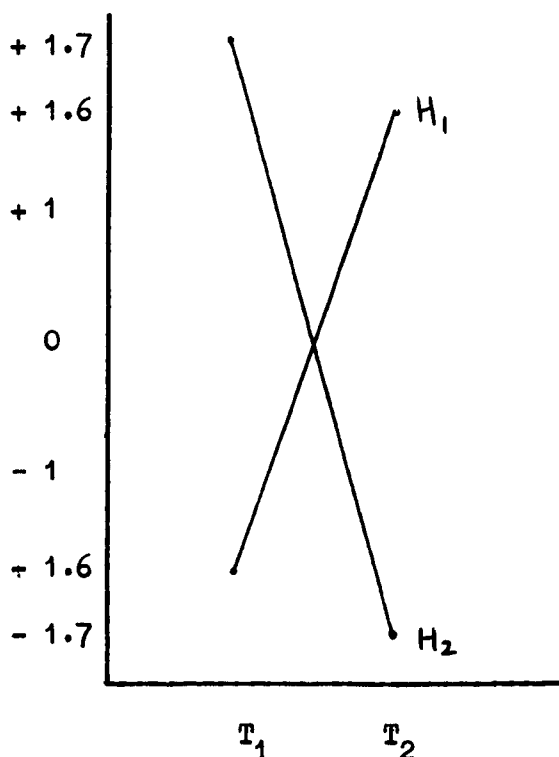
This shows that the interaction H x T is great after H and T effects have been eliminated.

At a high temperature T_1 , a low humidity greatly increases mortality, whilst a high humidity causes fewer deaths.

On the other hand, at a low temperature T_2, the effect of H x T is that a high humidity increases mortality and low humidity decreases it.

This latter effect is more difficult to explain than the former which is reasonable. Whatever the effects of H x T acting together, they are probably both masked by the very large

effects of H and T acting separately.   Perhaps the most interest-
ing fact to be gained from the above graph is that temperature in
conjunction with low humidity has more effect than with high
humidity.

T x F   n = 4

Mean values:

	F_1	F_2
T_1	35.05	34.6
T_2	19.2	22.2

Effects relative to G
after accounting for
main effects:

	F_1	F_2
T_1	+ 0.9	− 0.8
T_2	− 0.9	+ 0.8

Mean (F_1T_1) = 35.05 = $G + F_1 + T_1 + \underset{\sim}{F_1T_1} + \epsilon$

$= 27.77 - .65 + 7 + \underset{\sim}{F_1T_1} + \epsilon$

$\underset{\sim}{F_1T_1}$ = 35.05 − 27.77 + .65 − 7   =   .93

Mean (F_2T_1) = 34.6 = $G + F_2 + T_1 + \underset{\sim}{F_2T_1} + \epsilon$

$\underset{\sim}{F_2T_1}$ = 34.6 − 27.77 − .65 − 7   = −.82

Mean (F_1T_2) = 19.2 = $G + F_1 + T_2 + \underset{\sim}{F_1T_2} + \epsilon$

$= 27.77 - .65 - 7 + \underset{\sim}{F_1T_2} + \epsilon$

$\underset{\sim}{F_1T_2}$ = 19.2 − 27.77 + .65 + 7   = −.92

Mean (F_2T_2) = 22.2 = $G + F_2 + T_2 + \underset{\sim}{F_2T_2} + \epsilon$

$= 27.77 + .65 - 7 + \underset{\sim}{F_2T_2} + \epsilon$

$\underset{\sim}{F_2T_2}$ = 22.2 − 27.77 − .65 + 7   =   .78

<u>T x F</u>

When using the mean values (a) it can be shown that
although the lines are very close together, they are not parallel
and there must therefore be a significant reaction between T and F.
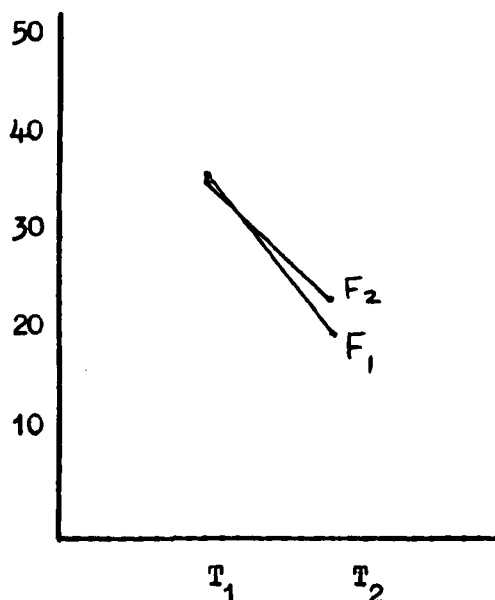
It shows that the effect of F is slightly more significant
at a lower temperature T_2 than at T_1.

When the separate effects of F and T are eliminated, this
graph is obtained, showing that there is a significant reaction
between F x T.   At a high temperature slightly more weevils which
have eaten food should be killed than those which have not eaten.
At the lower temperature the reverse is true.   In actuality the
effects of high temperature and low humidity are so great that the
effect of food alone is negligible.   The effect of T x F is also

over only a small area and is not very great.
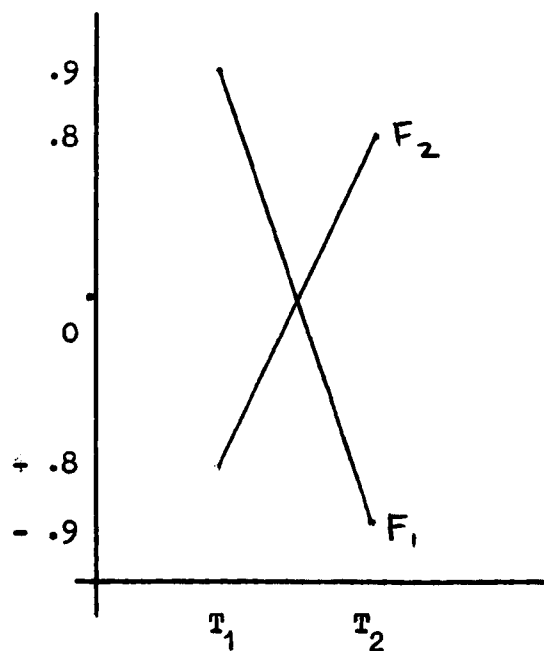
THREE FACTOR INTERACTIONS   n = 2

Mean values:
T_1

	H_1	H_2
F_1	25·5	44·6
F_2	23·3	45·95

(i)

Mean values:
T_2

	H_1	H_2
F_1	10·5	27·9
F_2	16.6	27.8

(ii)

Mean $(T_1 H_1 F_1)$ = 25.5 = $G + T_1 + H_1 + F_1 + F_1 T_1 + H_1 T_1 + \underset{\sim}{T_1 H_1 F_1} + \epsilon$

$= 27.77 + 7 - 8.8 - .65 + .9 - 1.6 + \underset{\sim}{T_1 H_1 F_1} + \epsilon$

$\underset{\sim}{T_1 H_1 F_1}$ = 25.5 - 27.77 - 7 + 8.8 + .65 - .9 + 1.6 = + .88

Mean $(T_1 H_1 F_2)$ = 23.3 = $G + T_1 + H_1 + F_2 + F_2 T_1 + H_1 T_1 + \underset{\sim}{T_1 H_1 F_2} + \epsilon$

$= 27.77 + 7 - 8.8 + .65 - .8 - 1.6 + \underset{\sim}{T_1 H_1 F_2} + \epsilon$

$\underset{\sim}{T_1 H_1 F_2}$ = 23.3 - 27.77 - 7 + 8.8 - .65 + .8 + 1.6 = - .92

Mean $(T_1 H_2 F_1)$ = 44.6 = $G + T_1 + H_2 + F_1 + T_1 F_1 + T_1 H_2 + \underset{\sim}{T_1 H_2 F_1} + \epsilon$

$= 27.77 + 7 + 8.8 - .65 + .9 + 1.7 + \underset{\sim}{T_1 H_2 F_1} + \epsilon$

$\underset{\sim}{T_1 H_2 F_1}$ = 44.6 - 27.77 - 7 - 8.8 + .65 - .9 - 1.7 = - .92

Mean $(T_1 H_2 F_2)$ = 45.95 = $G + T_1 + H_2 + F_2 + T_1 F_2 + T_1 H_2 + \underset{\sim}{T_1 H_2 F_2} + \epsilon$

$= 27.77 + 7 + 8.8 + .65 - .8 + 1.7 + \underset{\sim}{T_1 H_2 F_2} + \epsilon$

$\underset{\sim}{T_1 H_2 F_2}$ = 45.95 - 27.77 - 7 - 8.8 - .65 + .8 - 1.7 = + .83

<u>T x H x F</u>

The effects relative to G after accounting for the main effects and second order effects are:-

	T$_1$	
	H$_1$	H$_2$
F$_1$	+ .88	− .92
F$_2$	− .92	+ .83
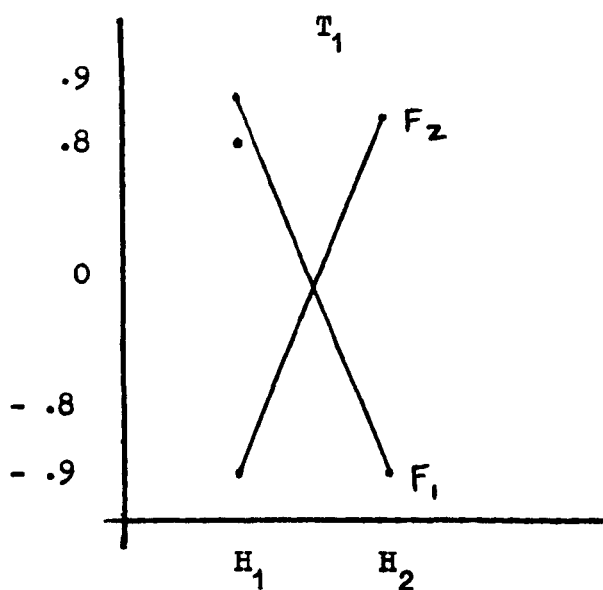
Although there is obviously some reaction of H x F x T, the figures are so low and close together as to make them hardly

significant.   In such a case, the mean values for H, F and T

from the tables (i) and (ii) would give us similar results.   For

the rest of the three order interactions only the mean values will

be used:
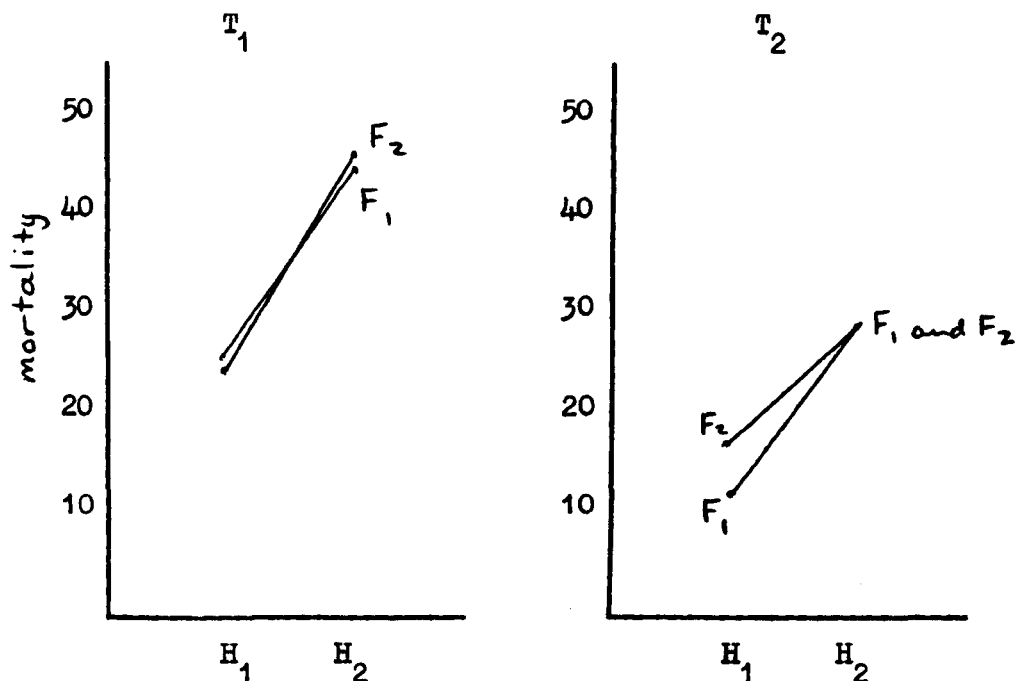
The first significant fact shown from the graphs is that

the reactions involving T_1 and T_2 are different from one another.

At high temperature T_1 , food whether present or absent

makes very little difference, whether the humidity is high or low.

There is greater mortality at H_2 whether the weevil has eaten or

not, than there is at high humidity.

At low temperature T_2 , the weevils which have not eaten, F_2 , show more mortality at high humidity than those that have eaten. When the humidity is low this H_2 effect probably masks any effect of food or absence of food.

THREE FACTOR INTERACTION T x H x L

Our first table (p.212) shows that this is not significant but has some small effect.

T$_1$

	H$_1$	H$_2$
L$_1$	24.7	44.0
L$_2$	24.1	46.6

(i)

T$_2$

	H$_1$	H$_2$
L$_1$	12.3	28.5
L$_2$	14.9	27.2

(ii)

The mean values involved are shown above. From these can be obtained the graphs:-
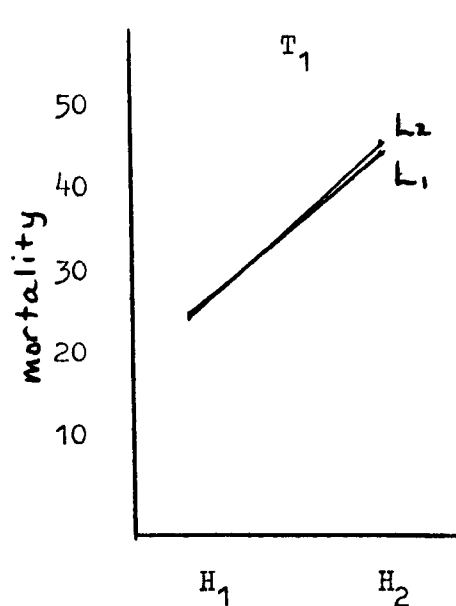
(i)
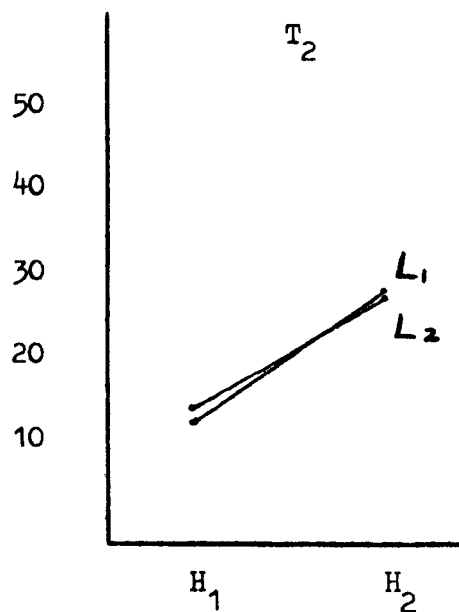
(ii)

It can be seen at once that these two graphs are different; therefore there must be some interaction between H x T x L.   This is only a very small interaction because the points are very close together, sometimes almost identical.

At a high temperature T_1 , and high humidity, the presence of light is of little significance, but at low humidity darkness slightly favours mortality.

Under T_2 or low temperature at high humidity, darkness slightly increases mortality.   The two results are inverted at different temperatures.

FACTORIAL EXPERIMENT 1964.

ii EGG LAYING.

In weeks 11 - 20 from 29th August to 8th November, using the same apparatus, weevils and treatments as described for the first 10 weeks, the humidity at H_1 was raised by omitting the lithium chloride and substituting water on filter paper. The factors used in each treatment are the same as those shown on p. 188, Table xxiv.

TABLE xxxv

NUMBER OF EGGS LAID IN 16 DIFFERENT TREATMENTS DURING WEEKS 11 - 20:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
7	2	45	26	0	0	0	0	0	0	37	0	0	0	0	0

T_1 (High)								T_2 (Low)							
H_1 (100% High)				H_2 (Low)				H_1 (High)				H_2 (Low)			
L_1		L_2		L_1		L_2		L_1		L_2		L_1		L_2	
F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2
6.0	1.7	38.5	22.2	0	0	0	0	0	0	31.6	0	0	0	0	0

+ Percentage of eggs laid weeks 11 - 20.

The number of weevils ovipositing in the different treatments are shown below. There were 10 weevils in each treatment:

Treatment No.	No. of weevils laying eggs	Total eggs
1	1	7
2	2	2
3	3	45
4	1	26
11	3	37
all others	0	0

Within the treatments, the eggs were laid as follows:-

1.	High humidity High temperature Light Food	One weevil laid 7 eggs in week 12 (the second week of the increased humidity).
2.	High humidity High temperature Light No food	Two separate weevils laid 1 egg each in week 18.
3.	High humidity High temperature Darkness Food	One weevil laid 30 eggs in week 12, then 5 in week 14. Another laid 6 in week 13, and the third laid 1 in week 12 and 3 in week 13.
4.	High humidity High temperature Darkness No food	One weevil laid eggs: 18 in week 12, 1 in week 13 and 7 in week 17.
11.	High humidity Low temperature Darkness Food	One weevil laid 12 eggs in week 11 and 6 in week 13. Another laid 6 in week 12 and 1 in week 16. The third laid 12 eggs in week 13.

CONCLUSIONS

      1.   Almost immediately the humidity was raised from 75% to about 100%, egg laying began in some treatments. This infers that a higher humidity is necessary for oviposition than for mere survival. No eggs were laid in the treatments with low humidity during weeks 11 - 20, thus any time-factor can be ruled out.

      2.   High temperature combined with high humidity is most favourable for ovipositing.

      3.   When humidity was high and temperature low, the only treatment to produce eggs had also both food and darkness. From the slender data available, after humidity and temperature have been considered, it would appear that both the absence of light and the presence of food are favourable for egg laying.

SIZE OF ADULT WEEVIL IN RELATION TO EGG LAYING

All the weevils in the Factorial experiment were measured and the average length of the 160 was 7.70 mm.   The nine weevils which laid eggs were on average 8.06 mm. and the two largest in the experiment, 8.80 mm. and 8.90 mm., were included in these nine. On the other hand, one of the ovipositing weevils was only 7.40 mm.

It would appear that above average length weevils tend to lay eggs earlier, but from such a small sample, most of which were under different environmental conditions, this result cannot be conclusive.

Part iii.   Amount of food eaten.

The amounts of food eaten were measured in square centimetres and the averages for each treatment calculated.   These were then expressed as percentages of the total amount eaten as shown below:-

T_1				T_2			
H_1		H_2		H_1		H_2	
L_1	L_2	L_1	L_2	L_1	L_2	L_1	L_2
19.6	21.3	9.5	10.1	10.4	17.1	5.0	7.0

After having the arc sin transformation applied to them, they were programmed and calculated by the computor for analysis of variance.

The results are shown on the next page. F was calculated by dividing the individual mean squares by the mean square of THL.

Source of variation	Sums of squares	Degrees of freedom	Mean squares	F	Significant at 0.5%
T	0.12079D+02	1	0.12079D+02	14.62	
H	0.13017D+03	1	0.13017D+03	157.40	
TH	0.18336D+01	1	0.18336D+01	2.22	
L	0.43945D+02	1	0.43945D+02	53.20	
TL	0.48828D+01	1	0.48828D+01	5.91	
HL	0.66701D+00	1	0.66701D+00	1<	
THL	0.82561D+00	1	0.82561D+00		
TOTAL	0.19440D+03	7			

Using the F tables for 1 : 1 we find that none of the factors is significant although humidity shows a large effect which is almost significant. Light, and to a lesser extent, temperature also show some effect.

In general, high humidity, high temperature and darkness favour feeding by C. singularis in this factorial experiment.

Under normal circumstances weevils feed after dark on rhododendrons but some of the bushes showing worst damage at Keele were underneath a street lamp which was lit all night.

In a previous experiment in the laboratory darkness and light seemed to have little significance where feeding was concerned. It may be, as in grain weevils (Richards 1951), that some weevils are negatively phototropic and others are indifferent to light.

3.   A NEW RECORD FOR PYGOSTOLUS STICTICUS (FAB),

A PARASITE OF OTIORHYNCHUS SINGULARIS (L).

Two specimens of Pygostolus sticticus, (Fab.), a parasitic insect belonging to the family Braconidae, were observed in association with the Clay-coloured weevil, Otiorhynchus singularis (L.) in Spring, 1964 at Keele in Staffordshire.

One was found after dark, ovipositing on the back of a weevil which was eating into the margin of a leaf of Rhododendron ponticum in the woods.

The second one hatched from a cocoon in the laboratory. The dish also contained a weevil, O. singularis which afterwards died.

During the following year I observed many more of these parasites hatching from cocoons after emerging from female weevils housed in petri-dishes in the laboratory. In all cases the host died within 24 hours of the parasite leaving the body, and none of these weevils laid eggs before dying.

All the P. sticticus were females (Pl. 40), and they were identified by Jean A.J. Clark of the Department of Entomology, British Museum (Natural History), to whom I express my thanks.

According to Marshall (1889) and the British Museum collection, this species has not before been recorded on O. singularis although, Clark says, another species of Pygostolus, P. falcatus, has been bred from the weevil and other related Curculionidae.

Pygostolus sticticus has previously been recorded (Marshall 1889) from the following hosts:

<u>Pterostoma palpina</u>(L.) (Prominent Moth. Notodontidae. Lepidoptera.)

<u>Agonopterix angelicella</u>(Hub.)(Syn. <u>Depressaria angelicella</u>).

(Tineid moth. Lepidoptera).

<u>Nematus ribesii</u>(Scop.) (Syn. <u>Pteronidea ribesii</u>).

(Currant Sawfly. Hymenoptera).

<u>Macrophya ribis</u>(Schr.)

Although some of these are again recorded by other authors

(Picard 1914; Morley and Rait-Smith 1933), they appear to have used

Marshall for their information and have not personally verified them.

As the above records on Tenthredinidae and Lepidoptera have not

been substantiated and as other species of <u>Pygostolus</u> are predominantly

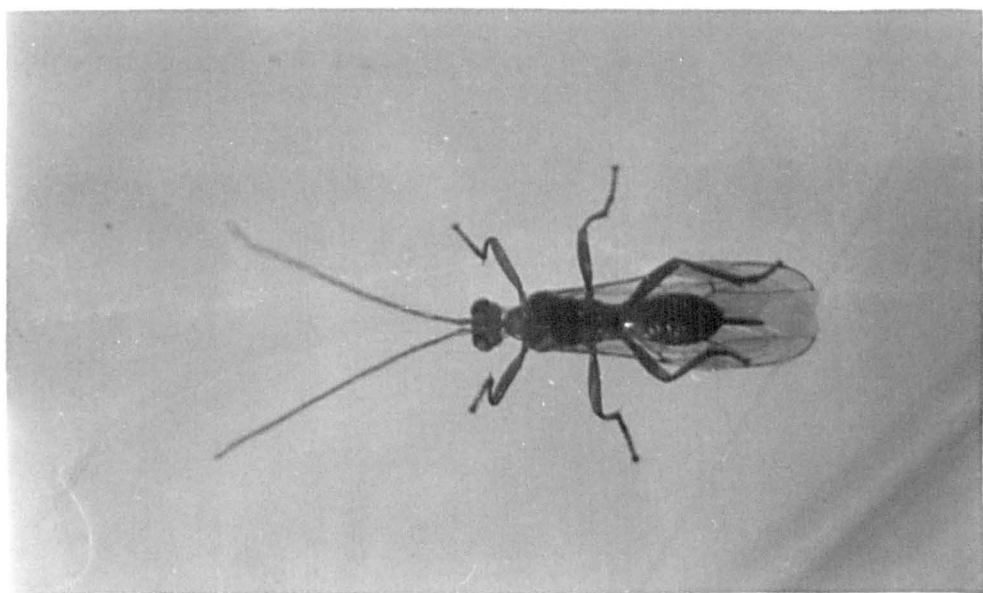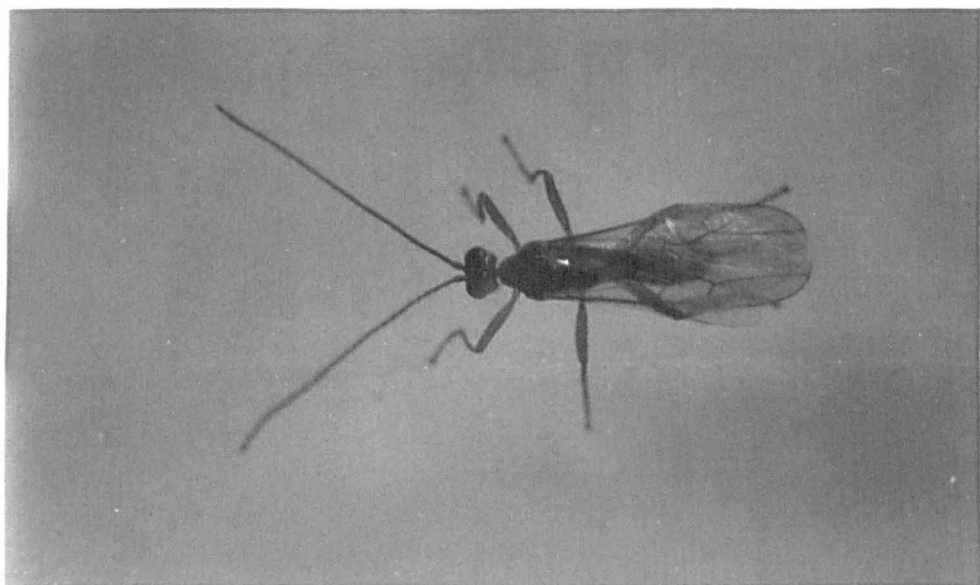on weevils, they now seem quite unlikely.

<u>Pygostolus sticticus</u> adult.

× 7·5

a. dorsal.

b. ventral.

<u>Plate 40.</u>

<u>ADULT</u>

The insect is described by Marshall (1889) as follows:-

"<u>Pygostolus sticticus</u> (Fab.)

<u>Ichneumon sticticus</u>, Fab. E.S., Suppl., 229 <u>Cryptus sticticus</u>, Fab.,

Piez., 89, ♀; <u>P. sticticus</u>, Hal., Ent. Mag., ii., 459; Ruthe, Berl.

ent. Zeit., 1861, p. 162, ♀.

<u>Bassus testaceus</u>, Fall., Spec. Hym. (not of Fab.), ♀.

<u>Blacus gigas</u>, Wesm., Nouv. Mem. Ac. Brux., 1835, p.99, ♀.

Rufo-testaceous, smooth and shining; eyes, stemmaticum,occiput,

variable portions of the mesothorax and pleurae, the pectus and sometimes

the scutellum, also the metathorax, and base of the 1st abdominal segment,

fuscous. Palpi whitish. Antennae dull ferruginous, darker towards the

tips, each joint of the flagellum annulated, fuscous at the extremity.

Metathorax punctatorugose, without raised lines or areae. Wings hyaline,

stigma yellow; costa, radius, anal nervure and part of the praebrachial

fuscous, the other nervures ferruginous; cubital nervure obsolete for a

great portion of its length. Abdomen shorter than the thorax, and at its

widest part not narrower, oblongovate above; if viewed laterally, obliquely

truncate behind; the sides of the 1st segment diverge as far as the obtusely

prominent tubercles, which are placed before the middle; thence to the apex

the sides are nearly straight and parallel; 1st segment minutely articulated,

the rest smooth; suturiform articulation faintly visible at the sides.

Valves of the terebra lanceolate, stout, black, pilose. Male unknown.

Length, 2½; wings, 6 lin."

Dorsal

Ventral

Cap removed when adult emerged

Plate 41.
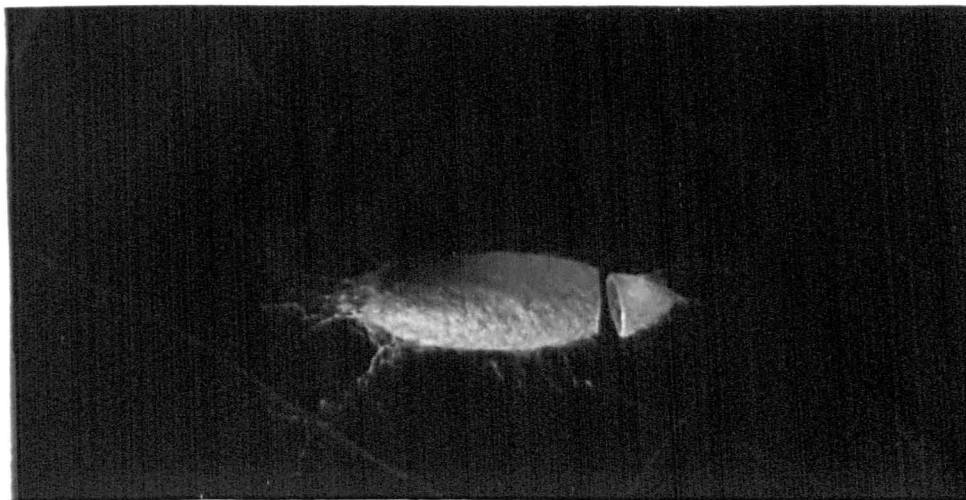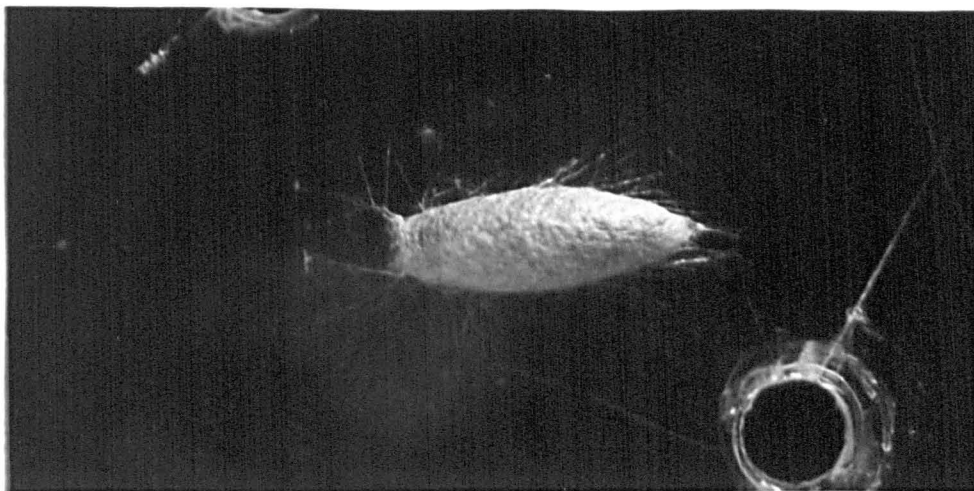
OBSERVATIONS ON PYGOSTOLUS STICTICUS

In all about 15 of these parasites emerged from O. singularis
during the summer of 1965 during a laboratory experiment which had to
be abandoned because of the death of the weevils.

LARVA:

The weevils were kept in separate petri-dishes or glass tubes
and the larva of P. sticticus, after leaving the weevil through the
posterior and usually during the night, would immediately begin to
spin a neat, white cocoon on the base or the lid of the dish.   Vigorous
movements were made as the larve used its mouth to place the threads
on to the surface, the head being rolled from side to side.

The white larva appeared to be legless with three pairs of white
pigment spots on the first three segments.   These segments were larger
than the others and greyer.   There were no hairs on the body.

A small ridge projected from seven of the abdominal segments and
the larva anchored itself whilst spinning by means of its tripartite
anal segment.   Before this, it appeared to move along by means of
horizontal contraction and extension of body segments.

I counted a pair of noticeable spiracles on each of the 2nd to 9th
abdominal segments and one pair on the 2nd thoracic segment.

The head bore prominent eyes and mandibles.

The length of the larva observed was 4.8 mm.
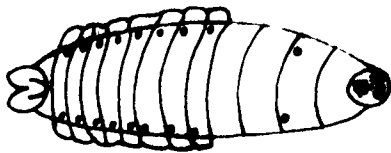
Ventral view of larva.   x 10

1 day old Pupa
dissected from
cocoon. x11
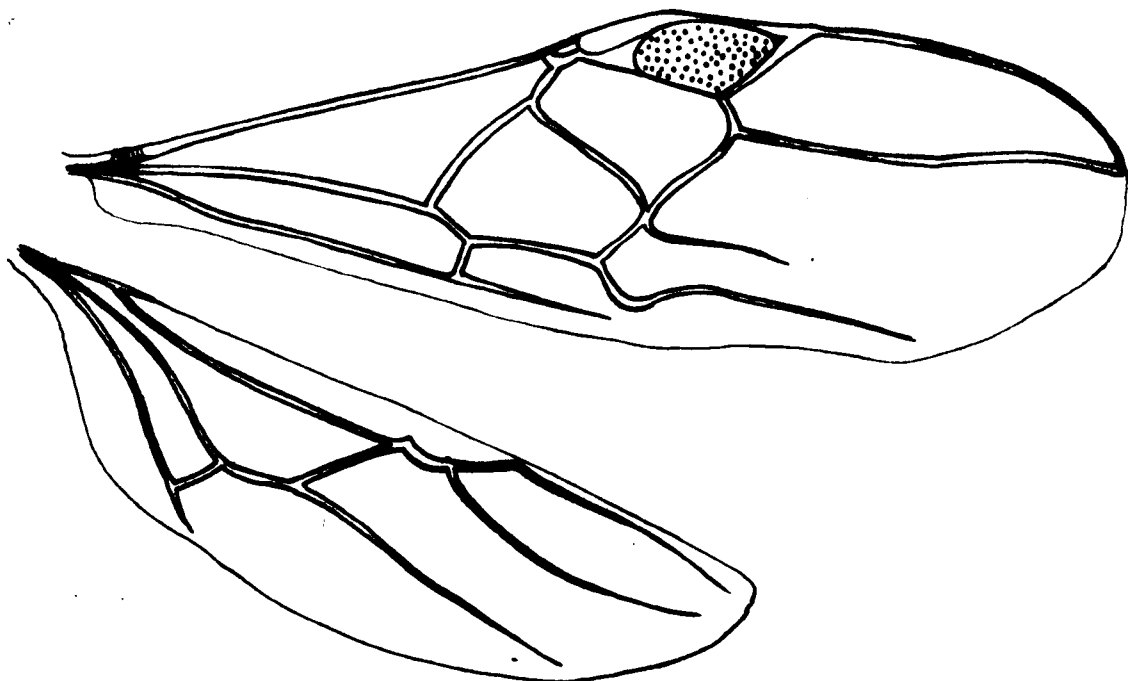
Wings of <u>Pygostolus sticticus</u>.   x 27

Fig.45.

COCOON:

Average size 6 mm. x 2 mm. White, cylindrical (Plate 41). The more rounded end of the cocoon appeared slightly darker than the rest. (Under hot, dry conditions the pupae did not mature but died and the co coon then turned brown). The pointed end of the cocoon is neatly cut off about 1 mm. from the end, allowing the imago to escape. (Marshall and the B.M. (N.H.) both report that the cocoons are normally reddish-grey).

PUPA:

It was difficult to examine the pupae because they shrivelled and died on exposure to the air and the microscope lights and heat. The pupa shown (Fig. 45) was 1 day old and measured 2.75 mm. long, 1.5 mm. wide at the widest part. It was greyish-white with yellow-grey eyes.

The times taken for the adult Brachonid to emerge from the pupa are shown below.

Date of larvae emerging from weevil and of cocoon being formed	Date of Imago emerging	Average Temperature °F	Number of days in cocoon
30th May	8th June	60	9
30th May	9th June	60	10
30th May	10th June	60	11
30th May	12th June	59	13
30th May	10th June	60	11
30th May	9th June	60	10
1st June	13th June	59	12
6th June	18th June	60	12

Average time of hatching from cocoon 11 days.

<u>ADULT</u>:

From my own observations I have noted the following average
lengths:-

		mm.
From head to tip of ovipositor		5.0
Head		0.5
Thorax		1.5
Abdomen		2.0
Ovipositor		1.0
Wings		5.2
Antennae		6.2

Colour: Body, light brown, Wings transparent.
Eyes, black. Antennae and ovipositor,
dark brown.

Wings: These are drawn on a preceding page.

Antennae: 34 segments.

Sex: All were female.

They did not appear to eat in captivity, and died within
three days of hatching.

D I S C U S S I O N

Compared with other widely grown ornamental shrubs and trees in Great Britain, the genus Rhododendron suffers from only a few important pests. Some of these are found specifically on rhododendrons, including Rhododendron Whitefly, Rhododendron Bug, Rhododendron leafhopper and Azalea Whitefly, but are for the most part confined to a small number of counties in the South of England. These pests hardly seem to have spread in Great Britain since they were reported forty to seventy years ago.

This summer (1970) I have seen the Rhododendron leafhopper, Graphocephala coccinea adults on the leaves of Pink Pearl and several other varieties of smooth-leaved rhododendrons at a Garden Centre on Anglesey. The plants had been imported from Exbury, Hants, obviously with eggs already laid on the bud scales. During a warm spell the eggs had hatched successfully.

Last year I found Rhododendron Bug, Stephanitis rhododendri, at the same nursery, also on plants bought in from the South of England, but the rhododendrons were sold and away before it could be discovered whether or not the pest would die out in this part of the country.

There seems to be quite a new problem arising here from the recent quick sale of bushes from drive-in Garden Centres. Plants are bought by the centres and brought in by car from different parts of the country. As most of the large rhododendron nurseries

are in the south they are also in areas containing endemic rhododendron
pests, but because the rhododendron pests mentioned above do not
at first cause much damage to young plants, the nurseryman does not
always spray the plants to control the pests. Often he does not
recognize that he has a pest at that stage (e.g. the eggs of
Graphocephala coccinea are very well camouflaged on the buds), so
contaminated bushes are being spread quickly throughout the country.
Once at the Garden Centre, the plants are further distributed widely
by customers, often on holiday and far from the gardens where the
new plants will be grown, who again transport the bushes and pests
swiftly by the car. More rhododendron plants are being bought in
Britain than previously because of the extended use of sequestrines
in the soil enabling these acid-loving plants to be grown in soils
of a high pH.

Only a few years ago a gardener would buy plants grown by a
nurseryman in his area, but now this is changing. Even the local
nurseryman probably buys in rhododendrons from a specialist grower
of rhododendrons and because of the quick turnover, the local
grower will not spend money on spraying the plants even if he does
notice a pest.

In many areas such as the Midlands and the North of England
and Scotland the climate will most probably continue to control the
major rhododendron pests, but in warmer places e.g. the south west
of England, North Wales and Anglesey, the west coast of Scotland,
I would not be surprised to see small outbreaks of Rhododendron Bug,

Whitefly and Leafhopper in the near future. Perhaps the biggest

threat is from the leafhopper which could spread Bud Blast disease

throughout the country (Baillie and Jepson 1951).

It is interesting to note that rhododendron pests in the U.S.A.

and other parts of the world, differ from those in Britain. Some

of the more exotic beetles and wood wasps are excluded from the

British Isles by vigilant customs officials inspecting imported

plants, and by our colder climate.

Since the last survey was made on rhododendron pests in

Britain (Fox Wilson 1939) the status of some of the pests has changed

slightly. All the hemipterous pests mentioned above can be controlled,

if recognized in time, by organophosphorus insecticide sprays. If

these pests are allowed to spread it is because of neglect on the

part of the grower, or economic pressures on him, not because of a

lack of an insecticide.

Two other pests of small rhododendron plants have increased in

importance as rhododendron pests during the past 30 years, and are

perhaps a little more difficult to control. These are the tortricid

moth and the Clay-coloured weevil, O. singularis.

By the time the caterpillar of Tortrix is discovered it has

usually spun a web and tied the leaves of the plant together, damaging

them and also putting itself out of reach of all but systemic

insecticides. This moth was formerly a pest of oak trees but now

will infest rhododendrons whether oaks are present in the vicinity

or not.

Because the Clay coloured weevil is polyphagous it will
continue to live in the garden even if those on rhododendron are
sprayed. In one garden at Keele, Staffordshire, after several
insecticides had been tried to rid a heavy infestation of this pest,
handpicking regularly at night in summer was tried and now five years
later almost all the weevils have been eliminated. A grower of
nursery rhododendrons whose plants suffer badly from O. singularis
would be well advised to do the same, or to use handpicking alongside
on insecticide such as malathion as an effective control.

In the midlands and north of England and Wales, the Clay coloured
weevil O. singularis is present in greater numbers on rhododendron
and other plants than O. sulcatus the Vine weevil, contrary to
Fox Wilson's findings in 1938. It cannot be ascertained whether the
Vine weevil is still more common in the south of England where Wilson
worked or whether the clay coloured weevil has since spread and increased
in numbers and importance in the South also. I suspect that, as the
damage caused by both these weevils on rhododendron is identical,
Wilson often attributed it to O. sulcatus rather than O. singularis
without searching for the causal insect after dark. In most counties
I have visited in Britain during the past several years I have found
O. singularis regularly on rhododendron, but only twice found O. sulcatus.

Some other pests that are mentioned, such as Cockchafer Beetle,
Melolontha melolontha, Sandy chafer Serica brunnea and Leaf Cutting

bee (Megachile),Slugs, Aphis, are only local or spasmodic and not
of any great importance.

In the future the nematodes may become major pests of the genus
Rhododendron. Little is known yet about the effects of these animals
on rhododendrons but it could be that many "sick" bushes will be
attributed to them. Certain genera (e.g. Xiphenema and Trichodorus)
which have been discovered around the roots of rhododendrons are
known to transmit viruses to other plants (Jones and Jones 1964,
Southey 1965) and therefore a watch should be kept by horticulturists
for nematodes and virus diseases in rhododendrons.

The clay coloured weevil, Otiorhynchus singularis being by far
the most common pest on rhododendrons in Staffordshire, was examined
in a little more detail than the other pests and several experiments
were performed on the insect in the laboratory.

It is interesting to note the controversy which has been
continuing recently about the naming of the genus Otiorhynchus, for
although the original name is Brachyrhinus and this name (spelt now
with two 'r's in the middle) is still used in the U.S.A., in Europe
where the majority of the species are found, Otiorhynchus (again
usually with two 'r's) is commonly used. This latter name will
probably receive preference (Zimmerman 1961) and Otiorhynchus (with
one 'r') be accepted whilst the original name is suppressed. This
is contrary to the common practice used in Entomology where the
original name is the one most usually accepted. The use of Otiorhynchus
with one 'r' in this thesis has been recommended by the Zoological
Nomenclature Committee.

The details of the life history of O. singularis are still not absolutely clear, but those set out by Willis (1965), showing that the weevil does not have a straightforward annual generation, seem reasonable and the stages found by me in the soil and on the plants outside confirm his findings. Other Otiorhynchus species also are able to survive and oviposit during a second year.

The difference in larval sizes and imaginal sizes may be accounted for by some weevils taking an extra year for development.

There appears to be no "average" of numbers of eggs laid nor is there any consistency in the times or batches of eggs laid, some weevils laying a few eggs each day, others a large batch on only one day. The final numbers laid do apparently depend upon the type of food consumed, those on rhododendron laying fewer than those fed on raspberry or rosebay willow herb. Willis (1965) stated that more eggs were laid by weevils fed on strawberry than those eating rhododendron.

Why, if the weevil finds more nutritional value and lays more eggs after feeding on, say, wild raspberry or rosebay willow herb, does it sometimes feed on rhododendron leaves? Uvarov (1928) states that insects are guided to their natural foods by tastes and odours of various chemical substances which in themselves have no nutritive value. For example, certain caterpillars whose normal food is Umbelliferous plants would rather eat filter paper treated with essential oils found in Umbelliferae than eat fresh carrot leaves (Dethier 1941). O. singularis is obviously drawn to the rhododendron,

especially the wild R. ponticum, by its olfactory and possibly taste senses.

Laboratory experiments confirm this, the smooth leaved R. ponticum being more attractive than the more pungent species. Odour may become repellent to insects at higher concentrations (Dethier 1963) and this may be the reason why O. singularis is attracted to some but repelled from other species of rhododendrons.

It is known that insects can be attracted visually to plants eg. Melolontha melolontha flies to the dark silhouette of woods against the skyline (Schneider 1952) and some caterpillars climb the stems of stinging nettles partly due to the olfactory stimulus, but also because of the dark patterning of leaves against the sky (Markel and Lindauer 1965). It would be interesting to discover if the patterning of the rhododendron leaves at dusk against the sky attracted the weevils. This could partly account for the fact that most weevils go to feed on leaves already bitten previously, but this is more likely to be because these leaves, being injured, emit more leaf odour.

It is an accepted fact that the type of food eaten before oviposition can influence the numbers of eggs laid. In work on the Colorado beetle it has been found (Grison 1947) that the number of eggs laid depends upon the species of potato plant on which the females feed or even upon the age of the leaves within a species. Difference in egg numbers laid were found to be due to differences in the nutrients in the leaves.

In other insects the oviposition rate depends on the feeding habits of the larvae. Some mosquitoes lay the initial batch of eggs without having fed as adults, the numbers of eggs laid depending on the diet which the larval mosquito received (Weyer 1934).

In the case of O. singularis it may be a combination of both larval and adult diet influencing the oviposition rate. It has been difficult to discover the exact location of larvae which as adults feed on the roots of rhododendron and it is thought that they may be those found feeding on weeds and the roots of hedgerow plants nearby. The larvae therefore may have had mixed diets before the adults began to feed on rhododendron and this could in some way account for the very varied numbers of eggs laid.

The adult weevils vary enormously in the amount of food eaten before oviposition, as the laboratory experiments show. Some will eat rhododendron prior to ovipositing, others laid eggs after being starved of food for 17 or 18 weeks. More eggs are laid when the adult weevils feed beforehand but there seems to be no maximum amount which has to be consumed before oviposition takes place, as Willis found there was with O. sulcatus.

To emphasize that the amount of feeding does not seem to directly influence the number of eggs laid we can consider the experiment performed in the laboratory in 1963 when O. singularis ate amounts of rhododendron leaves in this descending order: deciduous azalea, glabrous, glaucous and yet laid eggs on these types in the proportion

155, 127, 237.   The ones eating the smallest amount laid the most eggs.
In this case most eggs were laid on the back of leaves with thick
indumentums and it could have been the texture of the leaf rather than the
food value which encouraged egg laying and/or presence of eggs
discouraging feeding.

More food is consumed by O. singularis immediately after egg laying
than before and I maintain that this is due to the uncomfortable distention
of the abdomen beforehand and the relatively empty abdomen in the post
egg laying period.

In the same experiment to find the factors affecting oviposition in
O. singularis, it was found that a high humidity and high temperature were
favourable for oviposition and this was confirmed in the factorial experiment
following.   This would agree with other workers experimenting on grain
weevils Calandra granaria where oviposition increases at 17°, 21° or 25°C
as the RH rises from 70 - 100% (Richards 1946).   With a constant RH the
rate of oviposition rose corresponding to rises from 17 - 25°C.   At the
other end of the scale, Richards found that oviposition ceased at 9.5^{o}C
but in the factorial experiment a few O. singularis eggs were laid at 6°C.
Eastham and McCully (1943) stated that the rate of oviposition varied
with RH and temperature but the total number of eggs of C. granaria did
not differ much, for the quicker the eggs were laid, the shorter the life
of the weevil.   This is not the case with O. singularis which lay
completely different totals of eggs.

They also found that the larger the weevil, the higher its
potential oviposition rate and that this was an effect of environment

and not the genetic constitution. From slender data available it would seem that the larger O. singularis may lay more eggs than the smaller.

Tsai and Chang (1935) working on C. oryzae found that oviposition could not take place at less than 60 - 100% RH and that the maximum number of eggs were laid at 24 - 29°C and 90 - 100% RH. The vital optima for O. singularis would appear to be near 100% RH and about 18° - 22°C.

In recent years many entomologists have worked on the separation of the larvae of Otiorhynchus species (van Emden 1950, Fowler 1963, Willis 1965) basing the identification upon the larval chaetotaxy. Although the position of certain seta on the 9th abdominal segment, over which Fowler and Willis do not agree, are not a reliable means of separating O. singularis from the larvae of O. sulcatus often found associated with it, there are other differing setal patterns on thoracic and abdominal segments which make this separation possible.

It is the adult clay coloured weevil which causes the damage to plants and which is the most interesting stage to the horticulturist. For this reason most of the work on O. singularis during this study has been carried out on the adult. I would consider it amongst the major horticultural pests, only going unnoticed by growers because of its habit of feeding on the plants after dark and hiding in the soil or leaf litter during the day.

The adults of Otiorhynchus have been described by Hoffman (1950) and Joy (1931) but the keys are often complicated using

characters only visible after much scrutiny under a microscope.
A simple key has been devised for the major British species which
should be useful to both the horticulturist and the entomologist.
All the six species have quite distinct markings on their frons, a
character not emphasised before.

O. singularis has been found on a wide range of garden plants,
soft fruits and weeds. Although the damage is for the most part
unsightliness, I have seen many young plants on which the severe
damage has proved lethal. In the rhododendron garden the plants
having smooth, glabrous leaves and the deciduous azaleas have their
leaves attacked more than the glaucous types. Cross sections of the
leaves show that the azalea has a much thinner upper and lower
epidermis probably making it easier for physical biting of the leaf.
The lower epidermis of the glabrous type is covered with long, branched
hairs and the upper epidermis is thickened with a cuticle also.
These combined with the often pungent smell of rhododendrons which
have an indumentum, apparently deter the weevil.

In the laboratory the adult weevils exhibited two features
which are worth noting. Firstly, the weevils aggregated together on
top of one another in the corners of cages or dishes and would spend
the day in this position. I have never found such an aggregation in
the soil or in leaf litter, nor seen any reference to such aggregations
in the soil.

Secondly, if held from behind along the sides of the elytra by
tweezers, the weevil would stretch out its legs and antennae to their

Plate 42.
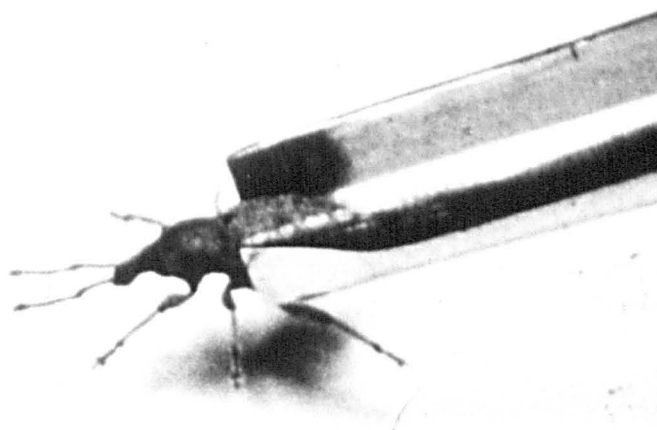
This photograph shows the aggressive position
taken up by O. singularis when touched at the
sides of the elytra. In this instance it was
picked up by forceps.

fullest extent in an aggressive movement. This fact was used in experiments when one needed to discover whether the weevil was dead or shamming, they never failed to appear aggressive if alive.

During this study a factorial experiment was performed to discover more of the weevils reactions to temperature, relative humidity, light and food in relation to longevity, oviposition and feeding habits. This was set up in 1964 initially for ten weeks and was to be repeated in 1965 using different levels, but an influx of the parasite Pygostolus sticticus killed so many weevils that the second experiment had to be abandoned.

The level of humidity was the greatest influence on the longevity of the adult weevils. At the low level when RH was between 12 - 40% the weevils only lived for a few days, especially those low humidities associated with the higher temperature. At high humidity 75% RH the weevils lived, many for the whole of the ten weeks. This result agrees with those found by other workers. Smereka and Hodson (1959) found that the granary weevil, Sitophilus granarius was more active at low humidities but remained alive longer in a higher humidity. They developed faster, lived longer and were more fecund at higher humidity.

Agriotes spp. react intensely to humidity and always migrate towards wet places even up to 100% RH (Lees 1943), Bursell and Ewer (1950) found that Peropatopsis moseleyi preferred a humidity of 98% RH, and Calandra granaria had maximum longevity at 70% RH (Eastham and

McCully 1943, Howe 1952).

On the other hand some insects prefer a lower humidity and Bentley (1943) writing about the biology and behaviour of <u>Ptinus tectus</u> shows that it lives longest at a low RH even thought it is most active at a higher humidity. Kennedy (1937) noted the same dry reaction in locusts. Gunn and Pielou (1940) show that <u>Tenebrio molitor</u> prefers dryness in a gradient of 5 - 10% RH.

Two other results are interesting: Wigglesworth (1941) showed that <u>Pediculus humanis corporis</u> avoided humidity of 95% and above but was indifferent to slightly lower values, and Thomson (1938) noted that a humidity of 60 - 80% was preferred by <u>Culex fatigens</u>. Both avoided the extremes of humidity and it could be that there are two types of receptors, one for wet and one for dry so that most insects avoid complete saturation.

<u>O. singularis</u> avoids low humidity and cannot survive in it. It will migrate towards a high humidity of 75% or over but it is not possible to say whether there is an upper limit above which the RH would prove fatal to the weevil. It would appear that <u>O. singularis</u> differs from <u>S.granarius</u> and resembles <u>Ptinus tectus</u> in that it is most active at higher humidities. The weevil moves and feeds after dark when the humidity is normally higher than during the day. Thus high humidity encourages activity as well as longevity .

Necheles (1927) suggests that cockroaches come out at night and are active because the temperature falls causing a rise in RH, the animals being hygro-positive. This I would agree with and believe that

this is the reason <u>O. singularis</u> feeds after dark. Experiments in the laboratory show that darkness or light have very little effect on the feeding habits of the weevil if the temperature and humidity remain the same.

From a previous experiment the upper limit for survival was found to be about $26^{o}C - 31^{o}C$, probably around $30^{o}C$ and a lower limit of about $5^{o}C$, but it is difficult to quote a temperature without also mentioning the relative humidity at the same time because both are interelated in their effects.

Gunn and Cosway (1938), when dealing with cockroaches, noted a kind of balance between pure temperature reaction and humidity reaction. This became apparent in my factorial experiment where not only was there an increase in mortality when the temperature rose but this increase became most noticable at low humidity.

At both high and low temperature levels (i.e. $6^{o}C$ and $18^{o}C$) there was greater mortality at a low rather than high humidity, but more interaction between T and H was apparent at high temperature than low. When the separate effects of temperature and humidity has been eliminated the true interaction effect of <u>T & H</u> showed that the high temperature and low humidity increase mortality, but at low temperature the reaction was less and low humidity decreased mortality. From both graphs, taken from the means and from the separate reactions, it is apparent that temperature differences have more effect at low humidity than at high. The latter effect tended to mask all others in the experiment.

Other workers have found similar interelationships between temperature and humidity. Reddy (1954) states that the rice weevil <u>Sitophilus oryzae</u> showed increased mortality at 30% RH with rise in temperature, and at 13% RH mortality rose as temperature increased from 20 - 35°C. The adults lived longer at lower temperatures. The same weevils (Qayyum 1964) were found to have a high mortality rate at 0 - 33% RH but they lived for a long time at 75 - 100% RH. At 40°C, at any humidity, death was caused and at 25°C with 0 - 33% RH also, but when at 0 - 33% RH the temperature was reduced to 5°C only 25% of the weevils died. Tsai and Chang (1935) stated that the lower temperature lengthened the life of the rice weevil because the metabolism was retarded and less energy lost. They quoted the maximum longevity as below 16°C and RH 85 - 100%.

Falconer (1945) working with <u>Agriotes spp</u>. wireworms found that the lethal temperatures for them were -3°C and 36°C and that when the temperature was lowered slowly there was more resistance to lower temperatures especially around -3°C. As the temperatures in the soil rarely exceed 0°C or 1°C at the lower level and 35°C at the upper (Russell 1937) the wireworms were never liable to death from temperatures in the soil. This will also be the case with <u>O. singularis</u>, except in the very rare cases when the top ½" of the soil rises above 32°C and when the weevil would have to bury deeper into the soil to avoid being dessicated.

Humidity, and to a lesser extent temperature also, had a definite effect on oviposition. No eggs at all were laid in the humidities up to 75% RH but as soon as water was substituted for the chemicals, eggs were laid by a few weevils. In all cases except one, the eggs were laid at the higher temperature. This agrees with the results obtained by Tsai and Chang (1935) for rice weevil, where maximum numbers of eggs were laid at 90 - 100% RH.

The presence or absence of food apparently has no real significance where longevity is concerned. The effects of humidity and temperature are so great that those of food are almost negligible in comparison. At a high temperature mortality is slightly greater amongst the weevils that have had food provided than amongst those that have had no food, but the difference is not significant. At a low temperature the difference in effect is slightly more noticeable and there is more mortality amongst weevils that have not eaten than amongst those that have. Reddy (1954) discovered the same reaction in adult rice weevils. At a high temperature, food exerted little influence on mortality, neither did it when the moisture content was low. At 73% R.H. few died when food was present.

Examining the results of feeding in the third part of the factorial experiment, we find that the weevil eats more at high temperature, high humidity and slightly more in darkness than in light, although the latter effect is not as great as effects of the two former ones. Again, with amount eaten, there is more contrast between

high and low himidity than between any other two levels of factors.

Different insects show very different reactions to light. In natural conditions O. singularis is photonegative, hiding during the day and becoming active after dark, as is Ptinus tectus (Bentley 1953). Wireworms show a negative reaction even to moonlight (Falconer 1945). Richards (1951) found that most grain weevils move away from the source of light but a small fraction move towards it, and that there are two types of weevils, those negative to light and those almost indifferent to it. In the laboratory O. singularis seems to fit into this last category because some of them will feed during daylight as well as in the dark. The factorial experiment shows that light is of very little significance to mortality rate; if anything at high temperature, low humidity, darkness slightly increases mortality and at low temperature, high humidity the result is the same. At low temperature, low humidity light increases mortality, but all these effects are masked by the large effects of humidity and temperature. The third section of the factorial experiment shows that darkness is slightly more favourable for the weevil to eat in, but again this is not as significant a fact as might have been expected. Weevils will feed on moonlight nights as well as on dark, moonless ones. When a torch is shone on them outside in the dark they do not react to the light by falling from the leaf as they do if the bush is disturbed and they feel the vibrations. They appear to show no reaction.

It is difficult, therefore, to categorise the weevils' reactions to light. They seem to be naturally slightly photonegative but for the most part are indifferent to light. More experiments could be carried out in this direction in the future. Little is known also of the photoperiodic effect of light on _Otiorhynchus spp._

Probably the weevil feeds at night due to the rise in humidity and drop in temperature rather than because of the darkness, although the dark night might protect it from birds and other predators.

To understand how the results obtained in the factorial experiment may be related to the conditions under which rhododendrons are grown, a little must be said about the temperature, humidity and light used by the grower when rooting the cuttings and growing-on the plants.

Cuttings are taken normally in July, August and September, trimmed to 3 - 4 inches, the stems dipped in hormonal rooting powder and placed in a well aerated and drained medium under mist. The mist provides a fine film of water on the leaves, keeping the humidity around the plant high.

The soil temperature is about 70°F (21°C) falling to 60°F and the air temperature 90°F (32°C).

During the day a minimum of 450 foot candles is essential and some form of supplementary lighting is sometimes necessary to finish off the cuttings for they may take from 10 weeks to 6 months to root depending on variety.

When rooted, the young plants are potted into acid peat in 3 inch pots and returned to the same house for a short time to form more roots. They are then placed in frames outdoors for gradual hardening, the pots being submerged in peat.   Later the rhododendrons are planted in rows in nursery beds and grown on until of a size to sell or transport to other nurseries and garden centres.

Although the high humidity on the leaves may encourage O. singularis to be active, to eat more and lay eggs, the constant wetting on the leaves would probably discourage the weevil from feeding on them.   Under saturated conditions in the laboratory the weevils have been seen to die.

The effect of the supplementary lighting and high summer light intensity would be negligible.

The adult weevil may be able to survive in the soil temperature of $21^{o}C$ but would probably not do so in the very high air temperature of $90^{o}F$ $(32-33^{o}C)$ in the greenhouse.   It is unlikely therefore that O. singularis will become a pest on rhododendron cuttings now commonly rooted under mist in the glasshouse.

When the plants are rooted, plunged into frames and planted out, they are then particularly susceptible to attack by the weevil, the temperature being lower.   Under frames the humidity is generally higher than outside and it is at this stage that the young plant is most vulnerable and at which time the grower should be most vigilant and examine the plants for weevil pests.

The Brachonid *Pygostolus sticticus* described by Marshall (1889) had not previously been found to be parasitic on *O. singularis* and specimens of this wasp and its host insect are now in the British Museum (Natural History). It seems likely that some of the other named hosts for this parasite may be erroneous as they have never been recorded since their first mention and are unlikely hosts for a *Pygostolus* species. Up to the present moment, *Otiorhynchus singularis*, although a pest in gardens and orchards throughout Britain and most of the world, has never reached epidemic proportions and the biological control afforded by the discovery of the parasite will most probably never be needed on any but the natural scale.

To sum up the position of rhododendron pests: at present they are of little consequence in Great Britain, but with a swiftly expanding rhododendron industry, with faster transport to all parts of the country, the grower should take care to recognise and control the pest at all stages, otherwise there could soon be a build up of insect pests in the warmer parts of Britain and a lowering of the standard of rhododendrons grown.

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