TROPICAL PEST BULLETIN 4

Seasonal distribution and migrations of *Agrotis ipsilon* (Hufnagel) (Lepidoptera, Noctuidae)

P Onyango Odiyo

CENTRE FOR OVERSEAS PEST RESEARCH

Ministry of Overseas Development

TROPICAL
PEST
BULLETIN
4

Seasonal distribution and migrations of *Agrotis ipsilon* (Hufnagel) (Lepidoptera, Noctuidae)

P Onyango Odiyo

East African Agriculture and Forestry Research Organization
P.O. Box 30148, Nairobi, Kenya

CENTRE FOR OVERSEAS PEST RESEARCH
COLLEGE HOUSE, WRIGHTS LANE, LONDON W8 5SJ, U.K.
1975

ISBN 0 85135 070 4

Price 75p net

Printed in England for Her Majesty's Stationery Office by
James Townsend & Sons Ltd., Exeter

Dd 151297 800 2/75

CONTENTS

	Page
Introduction	5
Material and method	5
Life history	5
Crop damage	5
Monthly distribution	6
Seasonal changes in distribution	8
Distribution of *A. ipsilon* and other Lepidoptera between North Africa and Europe in 1964	9
Discussion	10
Summary	11
Résumé	11
Acknowledgements	11
References	12
Maps	14

INTRODUCTION

The larva of the near-cosmopolitan noctuid moth *Agrotis ipsilon* (Hufnagel) (=*A. ypsilon, Rhyacia ypsilon* (Rott.), *R. ypsilon* (Warren), *Scotia ipsilon* (Rott.)) is popularly known as the greasy cutworm in Asia and North America, the dark sword grass in Britain, and the black cutworm in Europe. The name 'cutworm' reflects its feeding habit of cutting off plant seedlings at the base of the stem, and the adjectives 'greasy' or 'black' describe its greasy, earthy-brown, blackish or grey-green appearance which is due to its black head, numerous dark tubercles, and dorsal longitudinal dark stripes and lateral pale ones. The greasy cutworm can be of very considerable economic importance, not only because of its prolific and often localized breeding but also because its nocturnal feeding habits often cause outbreaks to escape notice until a late stage.

The sudden appearances of *A. ipsilon*, often in large numbers, and its seasonal disappearances, especially in India, the Celebes, Egypt and the Middle East, caused this pest to be recognized as a migrant about half a century ago. The present author has attempted to obtain additional circumstantial biogeographical evidence of major seasonal redistributions of populations on a world-wide basis, particularly over continental land masses and remote islands. This has been done by plotting historical records, obtained from museum specimens, light-traps and the scientific literature, on monthly distribution maps. This type of analysis has previously been undertaken for the armyworm moth, *Spodoptera exempta* (Walk.), in Africa (Betts, Haggis & Odiyo 1968), and for the Desert Locust, *Schistocerca gregaria* (Forsk.), throughout its vast distribution area in Africa, the Middle East and south-west Asia (Waloff 1946; Donnelly 1947; Davies 1952; Fortescue-Foulkes 1953). A further aim is to attempt an interpretation of the role of seasonal changes in the distribution of *A. ipsilon* as a natural means of adaptation.

MATERIAL AND METHOD

The primary sources of data were museum collections which the author examined in Amsterdam, Brussels, Leiden, London, Nairobi, Paris and Tervuren, and additional museum records obtained by correspondence from Denmark, Sweden, South Africa and West Germany. The author also searched for records in the literature, particularly in the *Review of Applied Entomology* for the years 1926–70, and in other entomological journals and reports, including the FAO *Plant Protection Bulletins*. Some data were also obtained from entomologists running private light-traps, and from the Commonwealth Institute of Entomology's *Distribution Maps of Insect Pests* (CIE 1969).

Records of all the satisfactorily documented museum specimens, totalling some 2000 individual moths and representing over one and a half centuries of collection, were plotted in the appropriate month and degree square of latitude and longitude on twelve composite 1 : 40 million world maps (Maps 2–13), and all the records from the light-traps and the literature were treated likewise. Three other composite maps were also drawn, one showing world distribution (Map 1) and the other two illustrating the contrast between winter and summer distribution (Maps 14 and 15). Finally, a specific example (Map 16), showing the distribution between North Africa and western Europe in 1964, was also drawn. This year was selected because there were several significant infestations.

LIFE HISTORY

Agrotis ipsilon lays from about 30 to 3000 eggs which take from 2 days to 2 weeks to hatch. The larval period lasts between 2 weeks and 3 months, during which period the larvae moult about five times at intervals of 2 to 6 days. Pupation takes place at a depth of up to 15 centimetres in the soil in earthen cells or cocoons and the adults emerge after about 10 days to 6 weeks. The adults can live from 1 day to 2 weeks before mating, with a total adult life of 12 to 20 days, or "over a month" (Bretherton 1969). The total life cycle therefore lasts about 1 to 4 months.

CROP DAMAGE

The greasy cutworm attacks a wide range of wild and cultivated plants, including maize, wheat, tobacco, cotton, peas, coffee, tea, cabbage and eucalyptus seedlings, but its status as a pest varies enormously in different areas. In some countries it poses a frequent threat of serious damage to economically important crops, for example in Argentina, Canada, Egypt (where over 400 km^2 of young cotton were destroyed in 1964 – FAO 1964), India (where about 100 km^2 of fertile Ganges flood plains are under "frequent and serious" attack – Kapur 1955), Israel and the Celebes. In other countries it only occasionally attacks crops, for example tobacco in Rhodesia, wheat in Greece (Soueref 1965), maize in Hungary (Meszaros & Nagy 1968), maize and tobacco in Bulgaria (Popov 1963), potatoes and other vegetable crops in Brazil (Pigatti & Pigatti 1966). Sometimes it occurs without causing noticeable damage, as in East Africa, Britain and other regions. The characteristic of causing very occasional severe damage in widely separated countries, in addition to more frequent damage in more regularly infested countries, is probably due to the mobility of the adults.

MONTHLY DISTRIBUTION

Northern winter and Southern summer (Maps 2–4)

December (*Map 2*)

Over the continental land masses, available records show that adults have been found in the Northern and Southern Hemispheres between 45 °N (south-east France) and 30 °S (South Africa), while in the Americas they have been found only in South America between 5 °N (Colombia) and 32 °S (southern Brazil). Larvae have been recorded from the Mediterranean region (Israel), the Nile Valley (Egypt and Sudan), India and Malawi (18 °S), and in the Americas in central Chile (39 °S).

Over islands, moths have been recorded in the South in Mauritius, Amsterdam (38 °S/78 °E) and New Zealand (42 °S), while in the North one moth, described by Bretherton (1969) as "the latest on record", was caught in Surrey, England on 5 December 1964.

January (*Map 3*)

Distribution of adults extends from Algeria (35 °N) and Cyprus (36 °N), the Middle East (Israel and Iran) and northern India (30 °N) to 30 °S in South Africa, while that in the Americas is from 35 °N in New Mexico and 34 °N in Florida to 34 °S in Uruguay. Larvae have been recorded in the Middle East (Israel), along the Nile Valley, in Zaire, Malawi, India and Burma.

Over islands south of the equator moths extend to 16 °S/5 °W in St. Helena, 21 °S/55 °E in Réunion and 41 °S in New Zealand, while in the North there is a report of *A. ipsilon* reaching southern England from north-west Africa or Spain with a warm wind trajectory in 1966 (Hurst 1969).

February (*Map 4*)

Distribution of adults is similar to that in January, but more widespread in Africa (Morocco, Nigeria, São Thomé, etc.) and India, while in the Americas records extend from Mexico to southern Chile (44 °S). Records of larvae extend from Algeria and India to Rhodesia and South Africa. Islands with moths include Norfolk (29 °S/168 °E), Hawaii and the Galapagos (0 °30'S/90 °30'W).

Northern spring and Southern autumn (Maps 5–7)

March (*Map 5*)

Apart from the record from southern Britain, adults have been recorded only up to 35 °N extending from Algeria through Pakistan to Burma, and in North America from Los Angeles (34 °N) in the west to lower Mississippi, west of Jackson. In the South, adults have been recorded up to Cape Town area (35 °S) in South Africa, in eastern Australia, and near Buenos Aires (35 °S) in South America.

Records of larvae extend across North Africa from Algeria to Arabia, then with a more northerly distribution across Asia from 35 °N in the Punjab via the western Himalayas to 31 °N in Hangchow, eastern China. Larvae have also been recorded in south-east Queensland and eastern New South Wales in Australia.

Records of adults from islands include those from the Canaries (28 °N/16 °W), Sri Lanka, Norfolk (29 °S/168 °E), New Hebrides (16 °S/168 °E), Samoa (12 °S/170 °W) and South Island (46 °S), New Zealand.

April (*Map 6*)

A wider and more northerly distribution of moths and larvae is seen over the continents, with moths being recorded from Britain and the Netherlands (53 °N), through Turkmenistan in southern U.S.S.R. to Korea and Hokkaido Island in north Japan. In East Africa, moths have been recorded at Entebbe (Uganda), Naivasha (Kenya) and Oldeani (Tanzania). Larvae have been recorded in Europe from Bavaria (50 °N), the Danube flood plains in Austria and around Bucharest in Rumania, in Asia in the Tigris Valley of Iraq, up the mountains of northern Nepal bordering on Tibet, in the Kameron highlands of Malaya and in eastern China, and also in Australia. In the Americas, adults have been recorded in the North around Los Angeles and southern Mexico and in Jamaica, West Indies, and in the South in western Bolivia, northern Argentina and Paraguay.

May (Map 7)

Further northward penetration of the continents by moths occurs up to 55 °N in Bakhmutovo, south-west of Moscow, U.S.S.R., to 51 °N in Inner Mongolia, south of the Amur river, and in the Americas to 42 °N in northern Illinois. In the South, moths have been found up to 25 °S in Botswana, 34 °S in New South Wales and 30 °S in Argentina. In Kenya, where *A. ipsilon* is rare but has occasionally been reported damaging maize (*Zea mays*) (Le Pelley 1959), moths have been caught in a light-trap at Muguga and also found near Mt. Elgon.

Larvae have also been recorded widely north of the equator from central Germany to the Sudan, from Nepal and the Hwang and Yangzte valleys in north-eastern China to Malaya, and around Chatham in south-eastern Ontario, and south of the equator near Lusaka (Zambia) and in eastern Australia (locality not recorded).

Northern summer and Southern winter (Maps 8–10)

June (Map 8)

Over the continents, moths and larvae appear to be widely distributed across western Europe, China and North America. In Europe, moths have been recorded as far north as 54 °N in Ireland and 53 °N in Germany, and larvae between 41 °N in Spain and 52 °N in Poland. In Asia, the most northerly records of moths have been from Peshowar in Pakistan to central China, Korea and Inner Mongolia (47 °N), while records of larvae extend from Burma to China. In the Americas, moths have been recorded between 51 °N at the foot of the Riding Mountains in Manitoba and 2 °S in northern Brazil, while larvae are only represented in the latitude of the Great Lakes (41 °N), as compared with breeding up to 40 °S in December.

No breeding appears to occur in India or the Nile Valley, while breeding in equatorial latitudes appears to be associated with highlands, e.g. in central Sri Lanka and the Kameron highlands of Malaya.

July (Map 9)

The preponderantly northerly distribution of adults and larvae now extends to 64 °N in Iceland, close to the Arctic circle (adults) (C. H. Lindroth and N. L. Wolff, pers. comm.). Records of larvae include the Jos Plateau (11 °N) in northern Nigeria and 46 °N in Nova Scotia, Canada.

August (Map 10)

Further penetration into the Northern Hemisphere is seen with reports of moths most numerous in western Europe, including all parts of the British Isles. The most northerly records now include Crieff and North Queensferry (57 °N) in Scotland (D. W. H. Ffennell, pers. comm.), the Norwegian highlands (61 °N) and Iceland (64 °N). In North America moths are recorded up to 49 °N near Quebec, 50 °N near Vancouver and 53 °N near Biggar in south-western Saskatchewan, while in the Southern Hemisphere they extend in Africa as far south as 31 °S near Durban, South Africa, and in South America to 32 °S in Argentina's Entre Rios plains.

Northern autumn and Southern spring (Maps 11–13)

September (Map 11)

Moths are still recorded in north-western Europe as far north as Iceland, and in North America to southern Canada. Records within the tropics include those of larvae from the Jos Plateau in Nigeria and moths from Muguga in Kenya, Sri Lanka, Sumatra, Bandung in Java, Panama, and the Amazon Basin in Brazil. Breeding in the North is still up to the Rhine Valley, also in Rumania and Poland.

October (Map 12)

There is still a predominantly northerly distribution, with a wide scatter in north-western Europe up to Norway and Iceland and across the eastern parts of North America, including Baton Rouge in Louisiana's Mississippi plains and 48 °N in Newfoundland. In the South, records begin to show a southward shift in South America, e.g. to Pelotas (32 °S/52 °W) in southern Brazil and Montevideo (35 °S/56 °W) in Uruguay, and in South Africa up to 31 °S near Durban.

November (Map 13)

Recorded southerly distribution extends as the northerly one decreases. Over the continents, moths extend in South Africa to 34 °S near Cape Town, in Australia to 37 °S in south-eastern New South Wales, and in South America to southern Brazil, while in the Northern Hemisphere, north-western Europe and the Middle East have a scatter of reports up to 53 °N in Britain and the Netherlands. Larvae are recorded in the Nile Valley and India.

Records of moths from outlying islands include those from São Thomé (0 °35'N/7 °E) in the Gulf of Guinea, Madagascar and Amsterdam in the South Indian Ocean.

SEASONAL CHANGES IN DISTRIBUTION

The monthly distribution of records of *A. ipsilon* during the periods December–February (Maps 2–4), March–May (Maps 5–7), June–August (Maps 8–10) and September–November (Maps 11–13) present geographical patterns which appear to be related to seasonal changes in the weather, especially temperature.

For instance, whereas during winter (Maps 2–4) in the Northern Hemisphere adults have been recorded in the continents only up to 45 °N in southern France and 30 °N in New Mexico, and larvae to 33 °N in the southern Mediterranean area, in the Southern Hemisphere adults have been recorded as far as 30 °S in South Africa and 44 °S in southern Chile, and larvae to 39 °S, also in Chile. Records at this period represent the most southerly limits of recorded distribution over land masses (Map 14).

During the Northern spring (Maps 5–7), however, moths have been recorded in Europe up to 53 °N in the Netherlands, in Asia to 30 °N in India, 55 °N in U.S.S.R. and 51 °N in Inner Mongolia, and in North America to 42 °N in Illinois, while larvae have been recorded, for instance, in Europe as far north as Austria, Rumania and 50 °N in Germany. In the Southern Hemisphere no significant changes seem to be caused by the onset of autumn conditions.

In the Northern summer (Maps 8–10), moths have been recorded further north to 64 °N in Iceland and 51 °N in Manitoba, Canada, and larvae to 52 °N in Poland, 35 °N in Pakistan, 38 °N in China and 46 °N in Nova Scotia (Map 15).

As the Northern autumn (Maps 11–13) cools gradually towards winter, distribution in the North shows some decrease while that in the South increases more noticeably. For instance, over the continents, moths extend southwards in November to 34 °S near Cape Town (South Africa), 37 °S in New South Wales (Australia) and to 32 °S around Pelotas in Brazil (South America), while to the north of the equator there are fewer records and they extend only as far north as 53 °N in the Netherlands and Britain.

From these seasonal changes in population distribution one can deduce that at least some migration takes place at the northern and southern limits of *A. ipsilon*'s range, and the following examples from the literature provide further evidence of migratory behaviour.

During the Northern spring (March–April) in southern Egypt, moths of the "third generation" after the hot dry summer, when all stages are absent, emigrate across and along the Red Sea into Israel and the Middle East with the result that in Egypt the species "cannot be found in any stage of development" in the summer (Pearson 1958), does not damage crops in lower Egypt "after the middle of May" (Williams 1925), and a special study in 1924–26 found that "all females captured in April were sexually immature" (Williams 1930).

In Israel, and the rest of the Middle East, where the greasy cutworm is described as a serious pest of crops and the most troublesome cutworm on maize (Rivnay 1962, 1964), or as the "most damaging" of all the species of Agrotinae (Rivnay & Yathom 1964), outbreaks of caterpillars and locusts featured amongst national calamities even during the reign of King Solomon who, in his "Dedication Prayer" about 469 B.C., prayed ". . . If there is famine in the land, if there is . . . locust or caterpillar; . . . then hear thou in heaven thy dwelling place, and . . . act . . ." (1 Kings 8 : 22 and 37).

Rivnay (1964) reports his findings (p. 306) and those of Williams (1930), that from the beginning of the summer (March–April) *A. ipsilon* appears to have a definite route of migration out of the African (Egyptian) shores, across the Red Sea, the Gulf of Aqaba and northwards into the mountains of Hermon and Lebanon where cooler conditions probably encourage breeding.

In India, where larvae often damage young conifer seedlings in the Punjab and the western Himalayas in the spring after the snow has melted from the seedbeds (Beeson 1935), and where larvae and moths in the Ganges flood plains are reported to disappear by April and May, the emerging moths are believed to migrate from the lowlands at the end of spring to the hills for breeding. In fact freshly dead moths were collected in June 1955 at 13–15,000 ft (4,100–4,600 m) on the Rohtang pass (32 °N) in the Himalayas (Kapur 1955) at a time (3–19 June) when the effects of the passage of an Inter-tropical front are likely to have been felt over the area (Brown, Betts & Rainey 1969). Later, after the floods of the June–August monsoon rains, frequent outbreaks occur on the newly ploughed flood-plains in Bihar along the Ganges (Kapur 1955; Williams 1930).

In Britain light-trap records for 17 years (1952–68) at Ottershaw and Bramley in Surrey include *A. ipsilon* between March (one specimen) and early December (one specimen) with the highest monthly numbers usually in August (Bretherton 1969). Predominantly male specimens caught in March, April and early May have on several occasions been "accompanied on the same or adjacent nights" by other species which are known to be migrants, e.g. *Nomophila noctuella* Schiff., *Heliothis peltigera* Schiff. and *Peridroma porphyrea* Schiff. (Bretherton 1969). Bretherton also states that "outward migration late in the year is perfectly possible".

In Belgium light-trap records show that *A. ipsilon* becomes "most abundant" during July–August and September–October (Van Daele & Pelerents 1965), and in Denmark, where immigrant populations usually appear in May, June or July, a "second immigration" of the moth is also recorded every year from late July to late August (Svend Kaaber, pers. comm.).

In Iceland *A. ipsilon* has been recorded only between July and October. It was one of the very first Lepidoptera to be recorded on the new volcanic island of Surtsey on 15 October 1964 (Lindroth and Wolff, pers. comm.).

Other examples of apparently migratory behaviour include the sudden appearance of large numbers of larvae on sprouting plants in East Wareham, Massachusetts in June 1944 after summer flooding on the Cranberry Station (Franklin 1945, 1946) and the repeated attacks on maize planted seasonally in dried lake bottoms from August in the Senkang Lake District in the Celebes (Franssen 1935). In Rhodesia noticeable attacks occur on early irrigated maize in late December following breeding in November (Rose 1962) and under certain circumstances moths tend to migrate to higher ground even when food is still abundant on the plains (Jack 1918).

Since *A. ipsilon* larvae are non-aquatic, and no other stages are known to be capable of survival under flood or snow conditions, it can only be deduced that those caterpillars which appear soon after the recession of floods or thawing of prolonged snow are the progeny of immigrant adults reaching these oviposition sites. However, outside the flood areas, the possibility of some moths emerging locally from diapausing pupae in temperate climates cannot be ruled out.

DISTRIBUTION OF *A. IPSILON* AND OTHER LEPIDOPTERA BETWEEN NORTH AFRICA AND EUROPE IN 1964

In 1964 there were several significant infestations of *A. ipsilon* in Egypt, Israel and Greece and many well documented instances of moths occurring across western Europe and into Iceland. Map 16 illustrates the distribution and dates of reports in these areas throughout 1964 and shows a progressive move northwards from North Africa to north-western Europe after April in line with the pattern of distribution in time and space presented by the composite records (see especially Maps 6–12) for this region.

Fuller details of the movements of *A. ipsilon* and other closely related species during this period are given below.

Between April and June, caterpillars of *A. ipsilon, Spodoptera exigua* (Hubner), *S. littoralis* (Walker) and other species attacked upwards of a quarter of over 4,700 km² of cotton at Beni Suef, Souhag, Kena and Minya in lower Egypt (FAO 1964).

On 9 May, about 200 *A. ipsilon* moths were attracted by light to the balcony and windows of a fourth-storey building in Ramat Gan, Israel, at a time when no previous local outbreaks had been reported, and on 13 May at 22.00 hours, about 300 *S. exigua* (a recognized migrant) and one *A. ipsilon*, among an estimated total of about 445 insects, were also observed at shop windows in Jerusalem (Bytinski-Salz 1966).

Between 9 and 21 May, seven *A. ipsilon* moths were caught at night in Rhodes Ixos by Mme Rothschild (British Museum (Natural History)), and in May, larvae of *A. ipsilon* caused severe damage to over 1000 acres (400 ha) of spring-sown wheat in Thesprotia, Greece (Soueref 1965). This was the first such outbreak on record in Greece.

On 20 May the first moth was caught at Hook, Hampshire, England, and between 21 May and 27 June, 16 moths were caught near Winchester (D. W. H. Ffennell, pers. comm.).

Between 14 July and 4 August a particularly sudden appearance of *A. ipsilon* moths was recorded in light-traps in Belgium where there had been no known larval outbreaks prior to this (Van Daele & Pelerents 1965).

On 17 July, one moth was caught near Winchester (Ffennell).

On 19 July, one moth was caught at Epen in the Netherlands (Amsterdam Museum).

In Denmark where the annual rhythm of *A. ipsilon* depends on its "spring time immigration", several specimens were noted in May, June and July 1964 and 1966, years when the species was "most abundant" (Svend Kaaber, pers. comm.).

Between 2 and 31 August, 60 *A. ipsilon* were caught near Winchester, the highest catch being 12 on the 28th (Ffennell). Two were also caught on 6 August at Northmoor, Oxford, and one on 28 August at Richmond, Yorkshire.

In August a large-scale migration of *S. exigua* and other migrants, including *Vanessa cardui* (L.), was recorded across north-western Europe to Finland and other Scandinavian countries (Mikkola & Salmensuu 1965).

Between 1 and 8 September, over 48 *A. ipsilon* were caught near Winchester and another 33 between 18 and 30 September (Ffennell).

Between 11 and 14 September, 125 moths were caught at Padstow, Cornwall, the peak being 107 on the 14th, and five were caught on 15 September at Coverack, Cornwall (Ffennell).

Between 1 and 3 October, seven moths were caught at Cap Gris Nez in France (Paris Museum).

Between 2 and 4 October a few moths were caught at Portland, Dorset, and on 11 October, three were caught at Lydd, Kent (Ffennell).

Moths were caught near Winchester throughout October, two on 1 October, 52 on 5 October, 12 between 6 and 10 October, and 85 between 15 and 30 October (highest 15 on the 28th) (Ffennell).

On 12 October *A. ipsilon* was recorded on mainland Iceland (the latest date since records have been kept), while on 15 October the first moth out of 15 in 1964 was recorded on the new volcanic island of Surtsey (Lindroth and Wolff, pers. comm.).

5 December 1964 is the latest date on which *A. ipsilon* has been recorded in Surrey, England (Bretherton 1969).

DISCUSSION

A. ipsilon is a near-cosmopolitan species whose range is limited by low temperatures and whose distribution shows a seasonal shift which is dependent on the varying temperatures throughout the year in the temperate latitudes.

The range of the moths appears to be greater than that of the larvae, suggesting that the adults are able to penetrate quite high temperate latitudes (up to 64 °N in Iceland and 61 °N in Norway) without being able to breed there, or at least without being capable of producing viable offspring. In less high latitudes *A. ipsilon* can probably survive throughout the year by some form of over-wintering or diapausing. For example, in Bulgaria "winter is passed in the pupal or older larval stages" (Nikolova 1961), and in parts of the U.S.A. the greasy cutworms "hibernate as pupae" (Crumb 1926). In Poland the larvae are reported to have "burrowed" into the soil to a depth of about 15 cm and constructed hibernacula where they "remained" from October till the following spring (Woroniecka-Siemaszko 1929).

In lower temperate latitudes, e.g. North Africa, the Middle East and India, where more severe attacks occur, there is evidence that *A. ipsilon* survives without diapausing. Here again the critical factor appears to be temperature, a high temperature being unfavourable for breeding so that the adults must migrate to cooler areas. For instance, in Egypt moths "migrate away from cultivated areas prior to the summer" (Pepper 1932), and the species "cannot be found in any stage of development" in the summer, "no resting stage" is known, and there is evidence of a "strong migration of adults" of the third (March–April) generation (Pearson 1958). In Israel, where the fourth generation in summer is incapable of proper reproduction because of high temperatures (often above 40 °C) and low relative humidity, the population in spring and autumn is "replenished" by an annual migration from the north coast of Africa to the mountains of the Lebanon and back (Rivnay 1964). In India, where a "close search" in the Ganges flood plains, which are subject to frequent infestations, failed to reveal *A. ipsilon*'s presence "in any stage" during the summer months, experimental breeding in the laboratory also showed no evidence of a "resting stage", and it was deduced that the species probably "habitually migrates" to the Himalayas at the end of spring (Kapur 1955).

A. ipsilon's presence in the adult form on such remote islands as the Canaries, São Thomé, St. Helena, the Galapagos, Easter, Amsterdam and Hawaiian islands, nearly 4000 kilometres from the nearest continents, could mean (a) that the specimens were indigenous (author unaware of any reference to local races), or (b) that they were immigrants from across the wide seas, having arrived on their own, or with unusual winds, or as a result of deliberate or accidental introduction by man or his agencies, especially shipping.

Other migrant insects have also been reported in more or less similar remote situations having travelled long distances. For instance, locusts have been reported in the Canaries and Madeira islands and in the Gulf of Guinea, some 800 kilometres into the Atlantic Ocean (Rainey 1963), and a Monarch butterfly, *Danaus plexippus* L., which was marked and released near Toronto, Canada, was recaptured four months later in Mexico, 3000 kilometres away (Rainey 1969). *Pantala flavescens* Fab., a well known migrant dragonfly, appeared in large numbers aboard a steamship during heavy rain on 11 April 1896 at night about 480 kilometres to the south-east of the Cocos Keeling Islands in the South Indian Ocean (Williams 1958), and in enormous numbers on a weather ship 450 kilometres south-east of Japan during the passage of the centre of a typhoon on 24 July 1967 (Asahina & Turuoka 1968).

In many of these cases, migrating insects tend to be closely connected with the prevailing seasonal winds associated with seasonal long and short rains. The relationships have been investigated in detail for a few species. Locusts, for example, have been shown (Rainey 1963) to be subject to the effects of the Inter-Tropical Convergence Zone and the extra-tropical depressions in the autumn. Down-wind displacement under such circumstances tends to concentrate the insects into convergence zones where the resulting seasonal rains ensure fresh plant growth for the offspring. No attempt has been made here to describe the seasonal wind systems which enable *Agrotis ipsilon* to migrate on such a wide scale but investigations have already been carried out for the closely related species *Spodoptera exempta* in eastern Africa (Brown, Betts & Rainey 1969) and *S. exigua* in Europe (Hurst 1969; Mikkola & Salmensuu 1965).

SUMMARY

The distribution of moths and larvae of *Agrotis ipsilon* (Hufnagel) has been plotted on monthly maps using data obtained from museum specimens, light-trap records and the literature. This has provided new evidence of major seasonal redistributions of populations which appear to be dependent on temperature.

Thus an absence of records of *A. ipsilon* north of 45 °N during December–March in continental Europe contrasts with the presence of the species as far north as 55 °N in the U.S.S.R. and 64 °N in Iceland during July–October; the absence north of 2 °N in China and Indo-China during October–December contrasts with breeding up to 31 °N in March, moths up to 38° and 44 °N in Korea and Japan respectively in April, and up to 51 °N in May; the absence north of 35 °N in North America during December–February contrasts with breeding up to 46 °N during May–August, and of moths to 53 °N during May–September. In the Southern Hemisphere, the absence of moths or larvae south of 3 °S in South America during June–July contrasts with the presence of larvae to 39 °S in Chile during December and of moths up to 44 °S during November–February.

In some areas *A. ipsilon* appears to be able to survive the cold by some form of diapausing or overwintering in the immature stages but in the higher temperate latitudes no evidence of breeding has been seen and the species can only live in these areas by immigration in the adult stage from populations produced in more equable latitudes.

A. ipsilon's presence on remote islands is a further indication of its ability to migrate long distances. It is deduced that *A. ipsilon* utilizes the same kind of seasonal wind systems as have been found to be an important factor in the migrations of other insect species.

RÉSUMÉ

La distribution des papillons et larves de *Agrotis ipsilon* (Hufnagel) pointée sur des cartes mensuelles en utilisant des données provenant de spécimens de musée, de pièges lumineux et de la littérature apporte une nouvelle preuve d'importantes redistributions saisonnières de populations, qui semblent dépendre de la température.

Ainsi, l'absence d'*A. ipsilon* au nord du 45 °N de décembre à mars en Europe continentale contraste avec la présence de l'espèce jusqu'au 55 °N en U.R.S.S. et 64 °N en Islande de juillet à octobre; son absence au nord du 2 °N en Chine et en Indochine d'octobre à décembre contraste avec des reproductions jusqu'au 31 °N en mars, des adultes jusqu'au 38 °N en Corée et 44 °N au Japon en avril, et jusqu'au 51 °N en mai; son absence au nord du 35 °N en Amérique du Nord de décembre à février contraste avec des reproductions jusqu'au 46 °N de mai à août, et la présence d'adultes jusqu'au 53 °N de mai à septembre. Dans l'hémisphère austral, l'absence de papillons ou de larves au sud du 3 °S en Amérique du Sud en juin juillet contraste avec la présence de larves jusqu'au 39 °S au Chili en décembre, et d'adultes jusqu'au 44 °S de novembre à février.

Dans certaines régions, *A. ipsilon* semble pouvoir survivre au froid par diapause ou hivernage aux stades immatures, maix, aux latitudes tempérées plus hautes, aucune preuve de reproduction n'a été observée et l'espèce dans ces régions ne peut vivre que par immigration au stade adulte à partir de populations produites à des latitudes plus clémentes.

La présence d'*A. ipsilon* sur des îles lointaines est une autre indication de son aptitude à parcourir de longues distances. On en déduit que *A. ipsilon* utilise des systèmes de vents saisonniers du même type que ceux qui jouent un rôle important dans la migration d'autres espèces d'insectes.

ACKNOWLEDGEMENTS

Many people have contributed towards the production of this work. I wish to thank especially Dr O. Starnes, former Director, EAAFRO, Muguga, and Dr P. T. Haskell, Director, Centre for Overseas Pest

Research, London, for arranging and supporting my training programme in the U.K.; the late E. S. Brown, former Head, Armyworm Research Division, EAAFRO, and Dr R. C. Rainey of COPR, London, for selecting and taking a very keen interest in the development and presentation of the subject; and Miss M. J. Haggis, also of COPR, for contacting various entomological museums, planning my itinerary in western Europe as well as advising on the cartographical presentation of the data.

The collection and documentation of most of the basic museum data was personally carried out in London, Paris, Brussels, Tervuren, Leiden and Amsterdam while I was in training. For help in providing and checking such data I am indebted to Dr I. W. B. Nye and D. S. Fletcher of the British Museum (Natural History), London; Dr P. Viette of the Museum National d'Histoire Naturelle (Entomologie), Paris; E. Janmoulle of the Institut Royal des Sciences Naturelles de Belgique, Brussels; L. A. Berger of the Musée Royal de l'Afrique Centrale, Tervuren, Belgium; Dr A. Diakonoff of the Rijksmuseum van Natuurlijke Historie, Leiden, Netherlands; M. Lempke (retired) and Dr G. L. Van Eyndhoven of the Zoologisch Museum (Entomologie), Amsterdam, Netherlands.

I am also grateful to the many naturalists in Europe, Africa and Asia who have provided me with additional data, especially Dr Heinz Schroder of Natur-Museum, Senckenberg, Frankfurt, W. Germany; Niels L. Wolff of the Universitetets Zoologiske Museum, Denmark; Prof. C. H. Lindroth of the Zoological Institute, Lund, Sweden; Svend Kaaber of 2 Digtervänget, Arhus, Denmark; Gurdas Singh of the Plant Production and Protection Division, FAO, Rome; Ali Hassanein El-Hamasey of the Plant Protection Department, Faculty of Agriculture, Cairo University, U.A.R.; J. C. Deeming of the Institute for Agricultural Research, Ahmadu Bello University, Samaru, Nigeria; J. A. Whellan of Bvumbwe Research Station, Malawi; B. W. Blair of the Department of Research and Specialist Services, Salisbury, Rhodesia; J. B. Muthamia of the National Agricultural Laboratories, Nairobi, Kenya; W. R. Ingram of the Agricultural Research Station, Gaborones, Botswana; and D. W. H. Ffennell of Martyr Worthy Place, Winchester, England.

I must also acknowledge the encouraging support I received from the librarian of the Commonwealth Institute of Entomology, London, while reviewing the past literature; the librarian of the Royal Geographical Society, London, while checking on gazetteers and maps; staff of the Scientific Information and Library Service of COPR, London, especially K. Smith, Miss P. Wortley, Miss A. Lumley and Miss D. Carter; and the librarian at FAO in Rome, while I was consulting the *Plant Protection Bulletins*.

My sincere thanks also go to C. F. Hemming and Miss J. M. Child of COPR for very useful suggestions and comments on the final draft; P. Ngugi of EAAFRO for helping with some of the drawings; A. K. Mohamed, former Head, Armyworm Division, for encouraging me to complete the work; and Dr B. N. Majisu, Director, EAAFRO for permission to publish this paper.

REFERENCES

ASAHINA, S. & TURUOKA, Y., 1968. Records of the insects which visited a weather ship located at the Ocean Weather Station "Tango" on the Pacific, II. *Kontyû* **36:** 190–202.

BEESON, C. F. C., 1935. Cockchafers and conifers. *India Forester* **1935:** 374–377.

BETTS, E., HAGGIS, M. J. & ODIYO, P. O., 1968. Seasonal distribution of *S. exempta* throughout Africa. *Rec. Res. E. Afr. agric. For. Res. Org.* **1968:** 122–123.

BRETHERTON, R. F., 1969. On rearing *Agrotis ipsilon* Hufnagel (the dark sword-grass) (Lep., Noctuidae). *Entomologist's Gaz.* **20:** 83–85.

BROWN, E. S., BETTS, E. & RAINEY, R. C., 1969. Seasonal changes in distribution of the African Army-worm, *Spodoptera exempta* (Wlk.) (Lep., Noctuidae), with special reference to eastern Africa. *Bull. ent. Res.* **58:** 661–728.

BYTINSKI-SALZ, H., 1966. Observations on migrating moths. *Israel J. Ent.* **1:** 193.

COMMONWEALTH INSTITUTE OF ENTOMOLOGY, 1969. *Agrotis ipsilon* (Hufn.). *Distrib. Maps Insect Pests* no. 261.

CRUMB, S. E., 1926. Tobacco cutworms and their control. *Fmrs' Bull. U.S. Dep. Agric.* no. 1496: 13 pp.

DAVIES, D. E., 1952. Seasonal breeding and migrations of the Desert Locust (*Schistocerca gregaria* Forskål) in north-eastern Africa and the Middle East. *Anti-Locust Mem.* no. 4: 57 pp.

DONNELLY, U., 1947. Seasonal breeding and migrations of the Desert Locust (*Schistocerca gregaria* Forskål) in western and north-western Africa. *Anti-Locust Mem.* no. 3: 43 pp.

FAO, 1964. *Plant pest and disease situation in the Near East Region.* Cairo, FAO Near East Regional Office Report no. 10: 8 pp. (Mimeogr.).

FORTESCUE-FOULKES, J., 1953. Seasonal breeding and migrations of the Desert Locust (*Schistocerca gregaria* Forskål) in south-western Asia. *Anti-Locust Mem.* no. 5 : 36 pp.

FRANKLIN, H. J., 1945. The Cranberry Station, East Wareham, Massachusetts (Report for 1944–1945). *Bull. Mass. agric. Exp. Stn* no. 428 : 28–30.

FRANKLIN, H. J., 1946. The Cranberry Station, East Wareham, Massachusetts (Report for 1945–1946). *Bull. Mass. agric. Exp. Stn* no. 436 : 29–30.

FRANSSEN, C. J. H., 1935. The biology of the cutworm *Agrotis ypsilon,* and its biological control in the Sengkang Lake District, South Celebes. (In Dutch with English summary.) *Landbouw, Buitenz.* **10:** 109–137.

HURST, G. W., 1969. Insect migrations to the British Isles. *Q. Jl R. met. Soc.* **95:** 435–439.

JACK, R. W., 1918. Cutworms (Part I). *Rhodesia agric. J.* **15:** 225–237.

KAPUR, A. P., 1955. On moths of the greasy cutworm, *Agrotis ypsilon* Rott., found dead in numbers on snow over Rohtang Pass, N.W. Himalayas. *Indian J. Ent.* **17:** 289–294.

LE PELLEY, R. H., 1959. *Agricultural insects of East Africa.* Nairobi, East African High Commission. 307 pp.

MESZAROS, Z. & NAGY, B., 1968. Outbreaks of the black cutworm (*Scotia ipsilon Hufn.*) in Hungary and comments on migration of adults. *Acta phytopath. Acad. Sci. hung.* **3:** 261–265.

MIKKOLA, K. & SALMENSUU, P., 1965. Migration of *Laphygma exigua* Hb. (Lep., Noctuidae) in North-Western Europe in 1964. *Annls Zool. fenn.* **2:** 124–139.

NIKOLOVA, V., 1961. Data on the bionomics of *Agrotis ypsilon* Rott. (=*Feltia, Rhyacia ypsilon* Rott.) and tests for its control. (In Bulgarian.) *Izv. tsent. nauchno-izsled. Inst. Zasht. Rast., Sof.* **1:** 83–109.

PEARSON, E. O., 1958. *The insect pests of cotton in Tropical Africa.* London, Empire Cotton Growing Corporation & Commonwealth Institute of Entomology. 355 pp.

PEPPER, H. H., 1932. Observations on an unidirectional flight of army cutworm moths and their possible bearing on aestivation. *Can. Ent.* **64:** 241–242.

PIGATTI, A. & PIGATTI, P., 1966. Complementary field tests for the control of *Agrotis ypsilon* (Rott.). (In Portuguese.) *Biológico* **32:** 250–252.

POPOV, P., 1963. A mass outbreak of *Agrotis ipsilon* (Hfn.) in 1963 in Bulgaria. (In Bulgarian.) *Rastit. Zasht.* **11** (10) : 27–31.

RAINEY, R. C., 1963. Meteorology and the migration of Desert Locusts: applications of synoptic meteorology in locust control. *Anti-Locust Mem.* no. 7 : 115 pp. (Also as *Tech. Notes Wld met. Org.* no. 54.)

RAINEY, R. C., 1969. Effects of atmospheric conditions on insect movement. *Q. Jl R. met. Soc.* **95:** 424–434.

RIVNAY, E., 1962. *Field crop pests in the Near East. Monographiae biol.* **10:** 450 pp.

RIVNAY, E., 1964. A contribution to the biology and phenology of *Agrotis ypsilon* Rott. in Israel. *Z. angew. Ent.* **53:** 295–309.

RIVNAY, E. & YATHOM, S., 1964. Phenology of Agrotinae in Israel. *Z. angew. Ent.* **55:** 136–152.

ROSE, D. J. W., 1962. Pests of maize and other cereal crops in the Rhodesias. *Bull. fed. Minist. Agric. Rhod. Nyasald* no. 2613 : 23 pp.

SOUEREF, S. T., 1965. Infestation of wheat by *Agrotis ipsilon* (Hfn.) in Thesprotia and tests on its control. (In Greek with English summary.) *Rep. Minist. Agric. Phytopath. Stn, Patras* **1963–64:** 34–35.

VAN DAELE, E. & PELERENTS, C., 1965. Population studies on cutworms and related species in the horticultural establishments of Ghent. (In Dutch with summaries in French, English and German.) *Meded. LandbHoogesch. Opzoek Stns Gent* **30:** 1524–1541.

WALOFF, Z., 1946. Seasonal breeding and migrations of the Desert Locust (*Schistocerca gregaria* Forskål) in eastern Africa. *Anti-Locust Mem.* no. 1 : 74 pp.

WILLIAMS, C. B., 1925. Notes on insect migration in Egypt and the Near East. *Trans. ent. Soc. Lond.* **1924:** 439–456.

WILLIAMS, C. B., 1930. *The migration of butterflies.* Edinburgh, Oliver & Boyd. 473 pp.

WILLIAMS, C. B., 1958. *Insect migration.* London, Collins. 235 pp.

WORONIECKA-SIEMASZKO, J., 1929. *Agrotis ypsilon* Rott. as an agricultural pest in Poland. (In Polish with English summary.) *Polskie pismo ent.* **7** (1928) : 193–201.

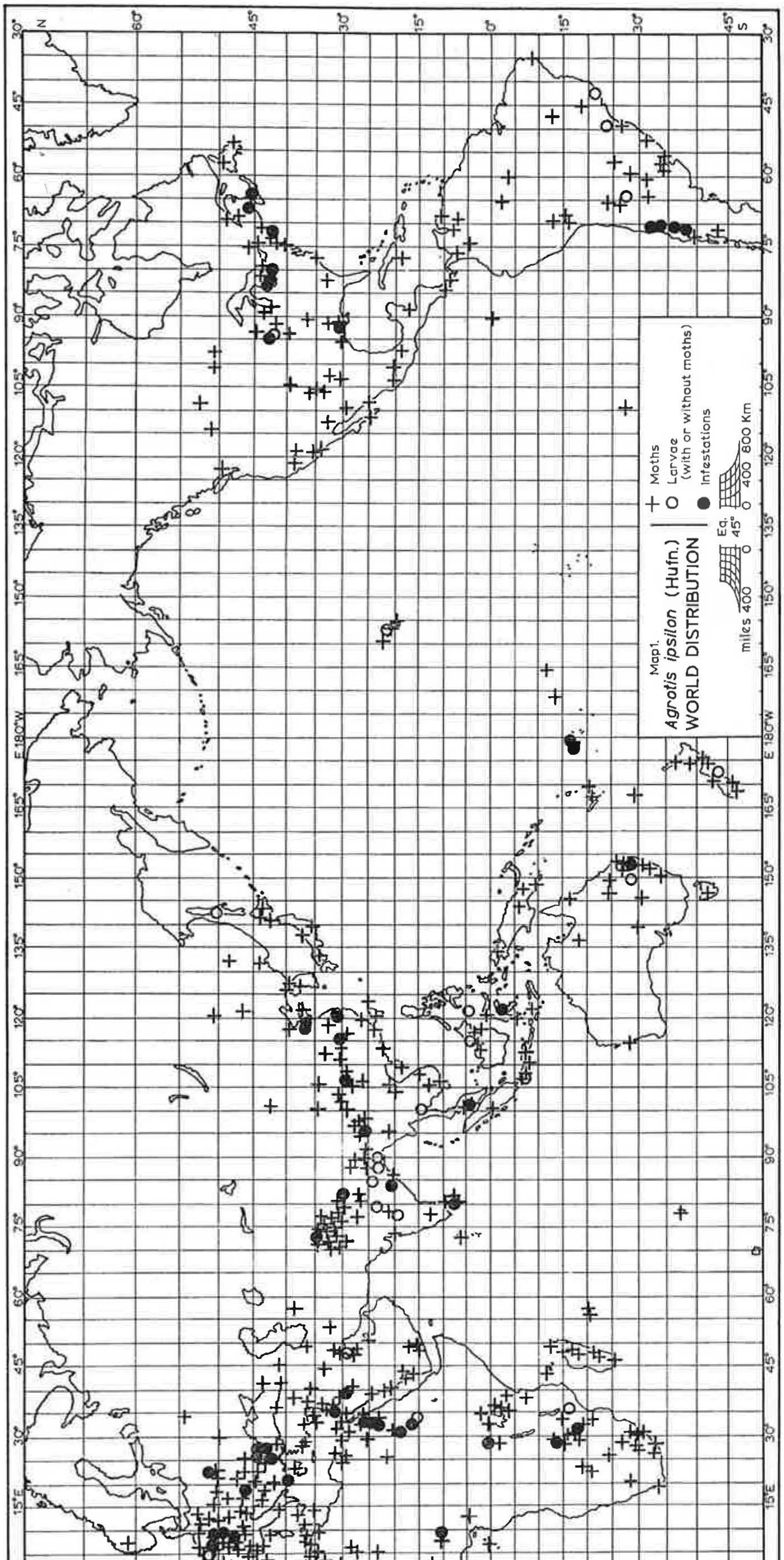
MAPS

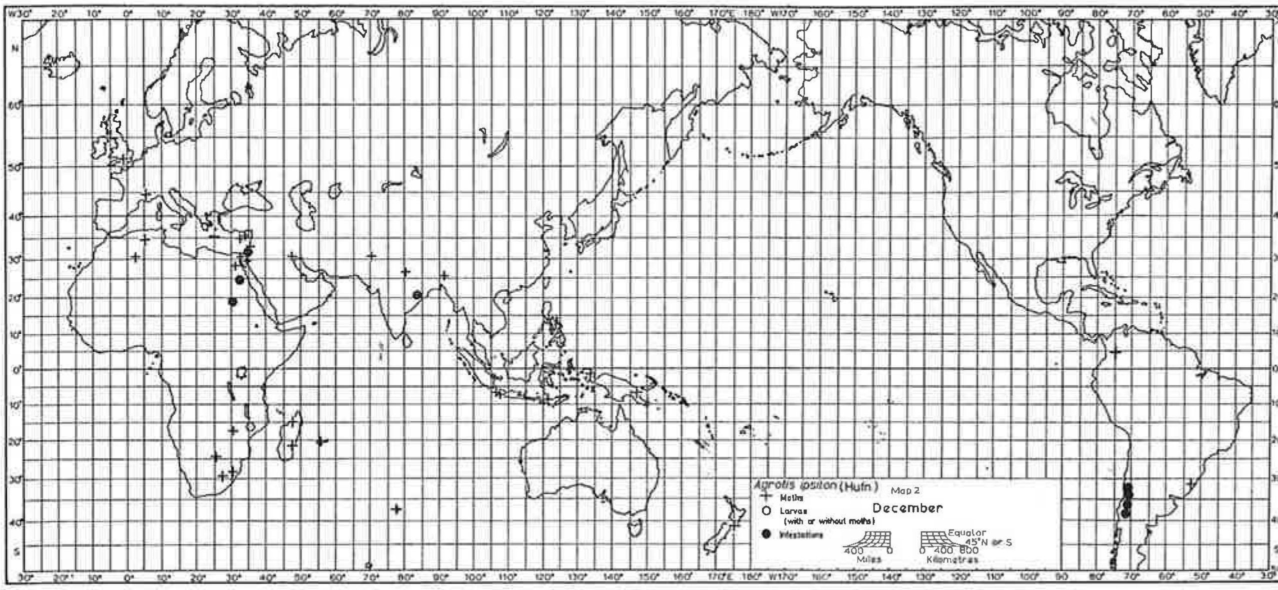
Map 1. World distribution of *Agrotis ipsilon* (Hufnagel).

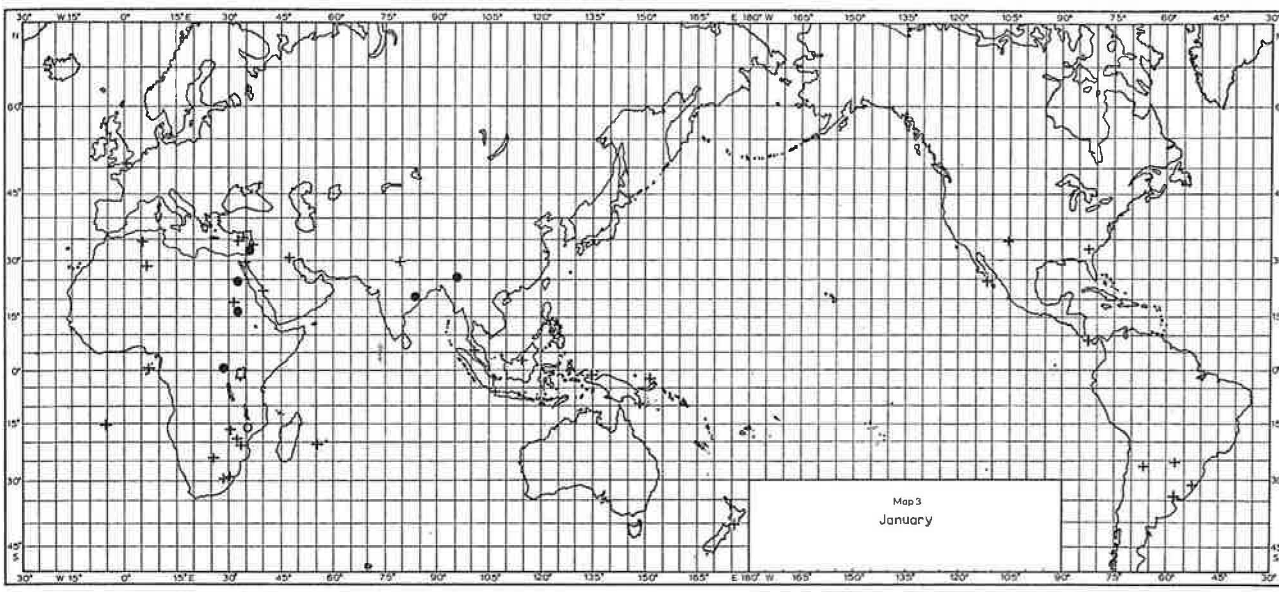
Maps 2–13. Monthly distribution (from December through to November) of *Agrotis ipsilon* (Hufnagel).

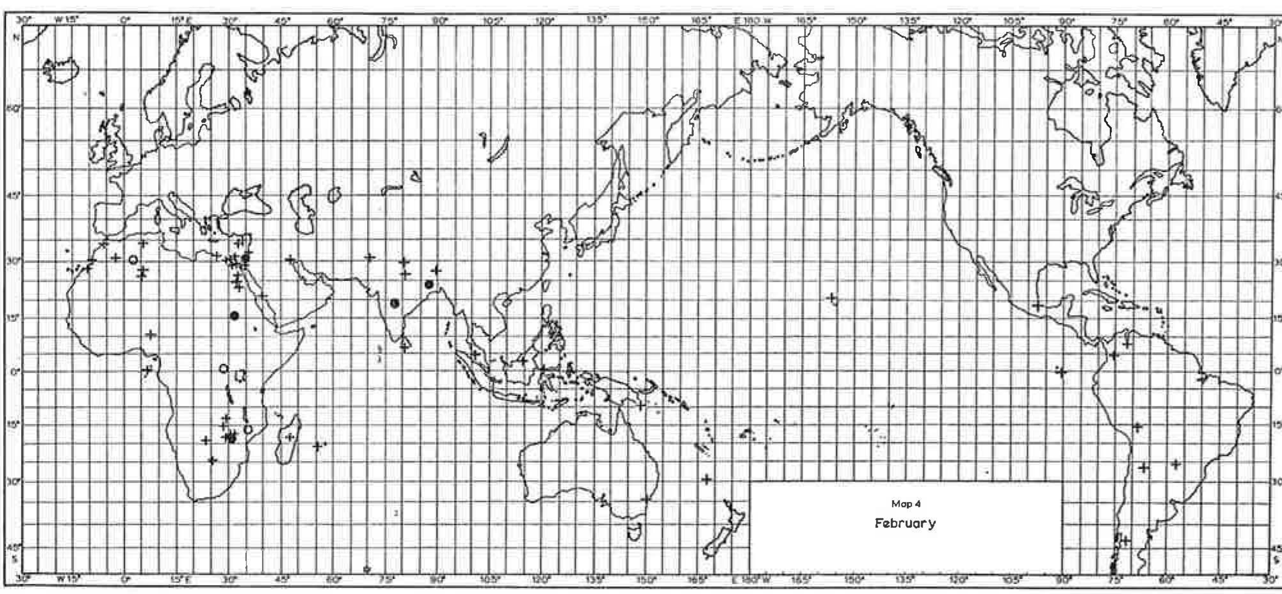
Maps 14, 15. Maps contrasting the distribution of *Agrotis ipsilon* (Hufnagel) at two seasons of the year: December and January, and June and July.

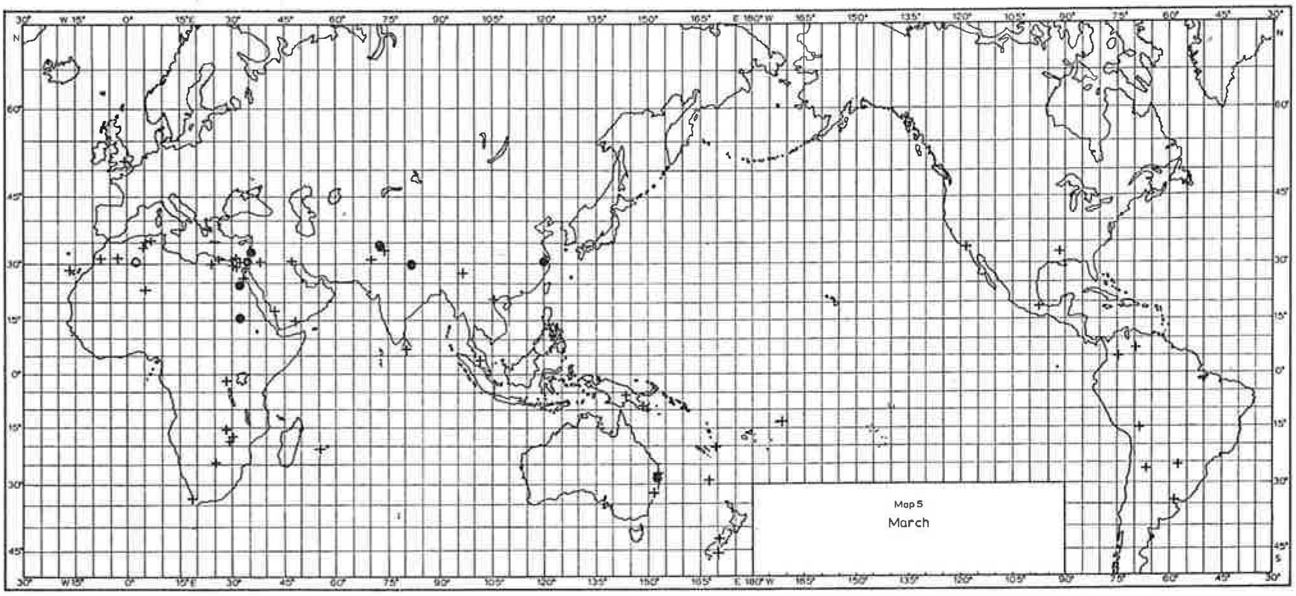
Map 16. Map illustrating the movement of *Agrotis ipsilon* (Hufnagel) and other Lepidoptera between North Africa and Europe in 1964.

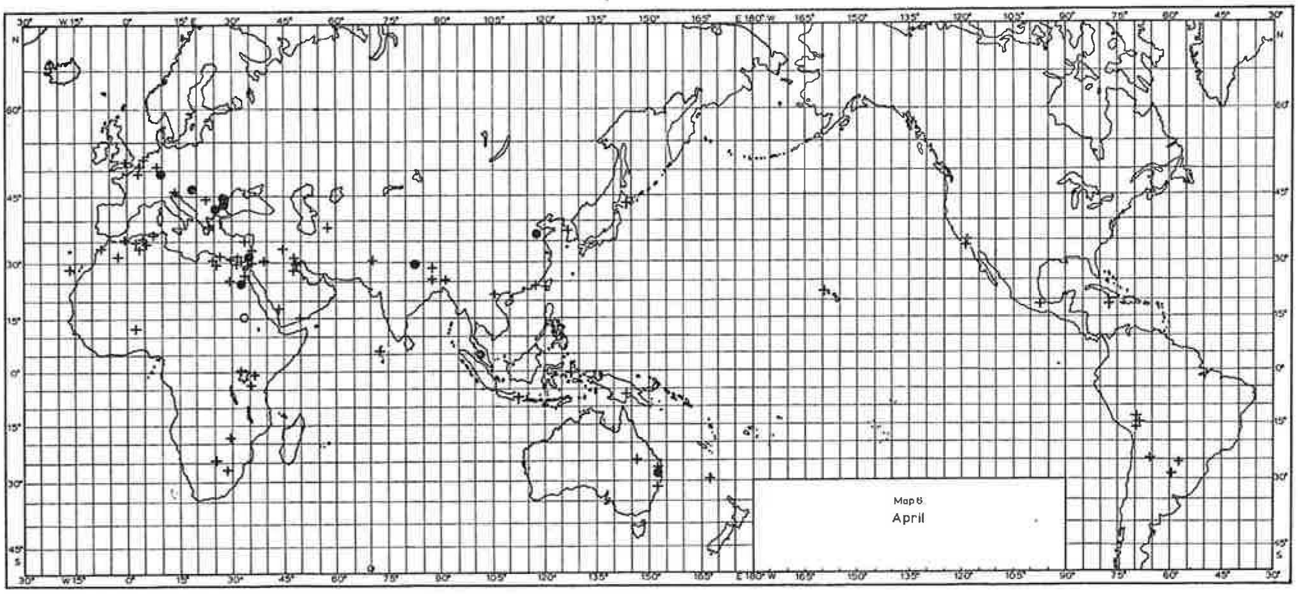

Map 1.
Agrotis ipsilon (Hufn.)
WORLD DISTRIBUTION
Moths
Larvae
(with or without moths)
Infestations
miles 400 0 400 800 Km
Eq.
45°

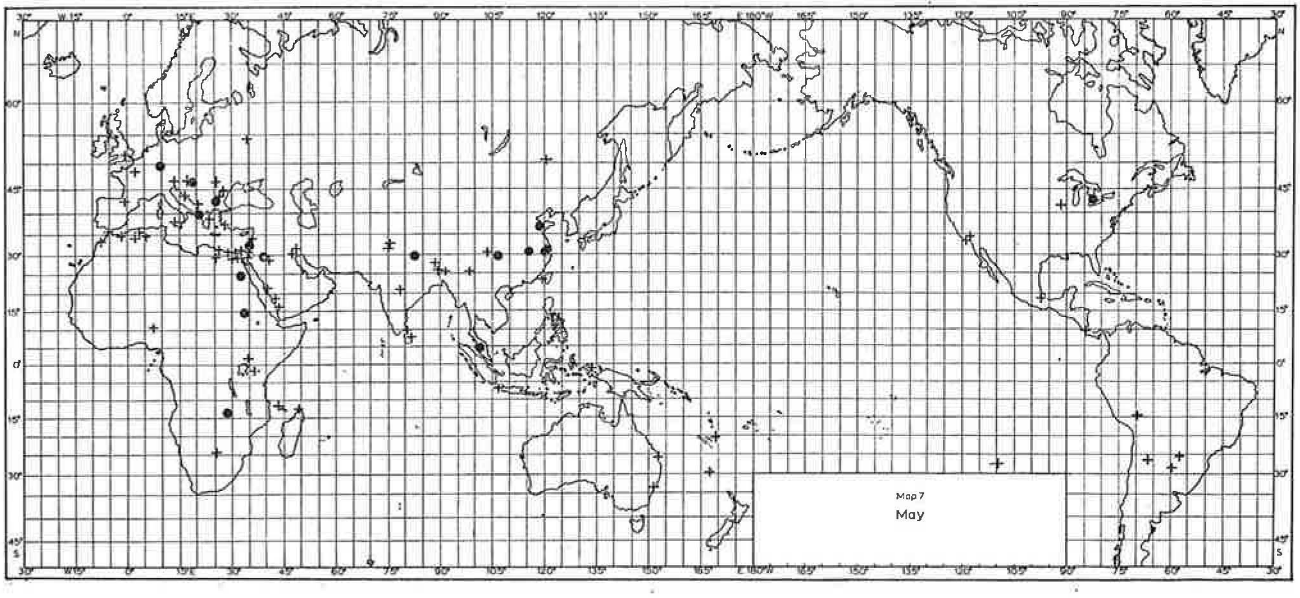

Agrotis ipsilon (Hufn.)
Map 2
December
Moths
Larvae
(with or without moths)
Infestations
Equator
45°N or S
400 0
Miles
0 400 800
Kilometres

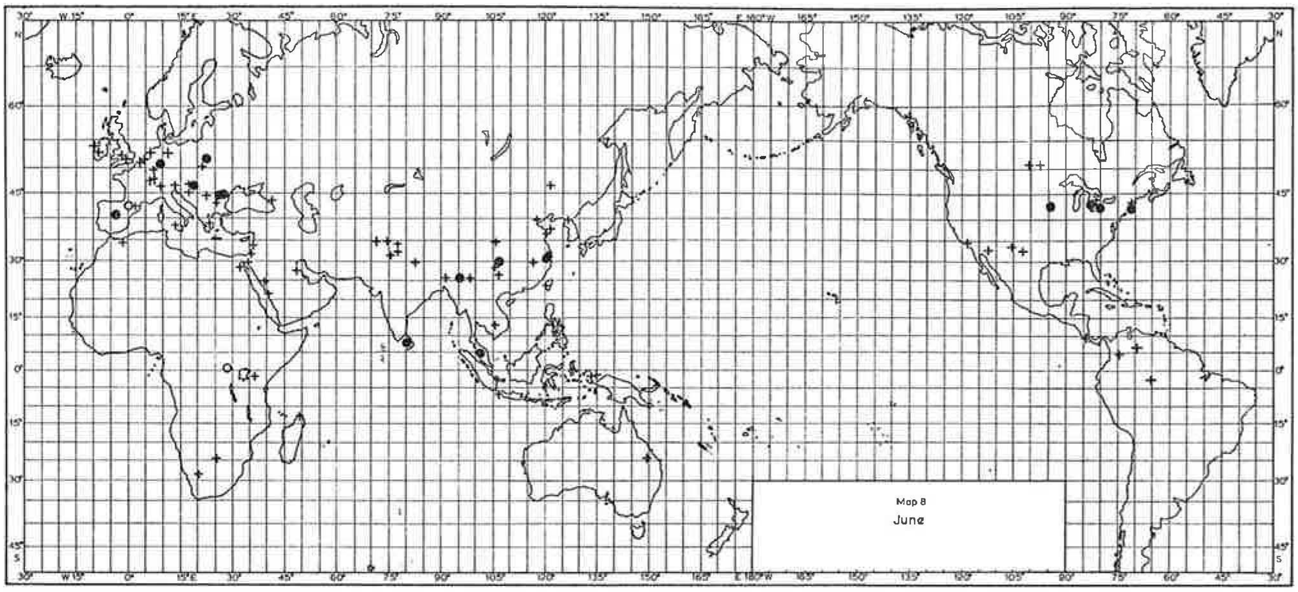

Map 3
January

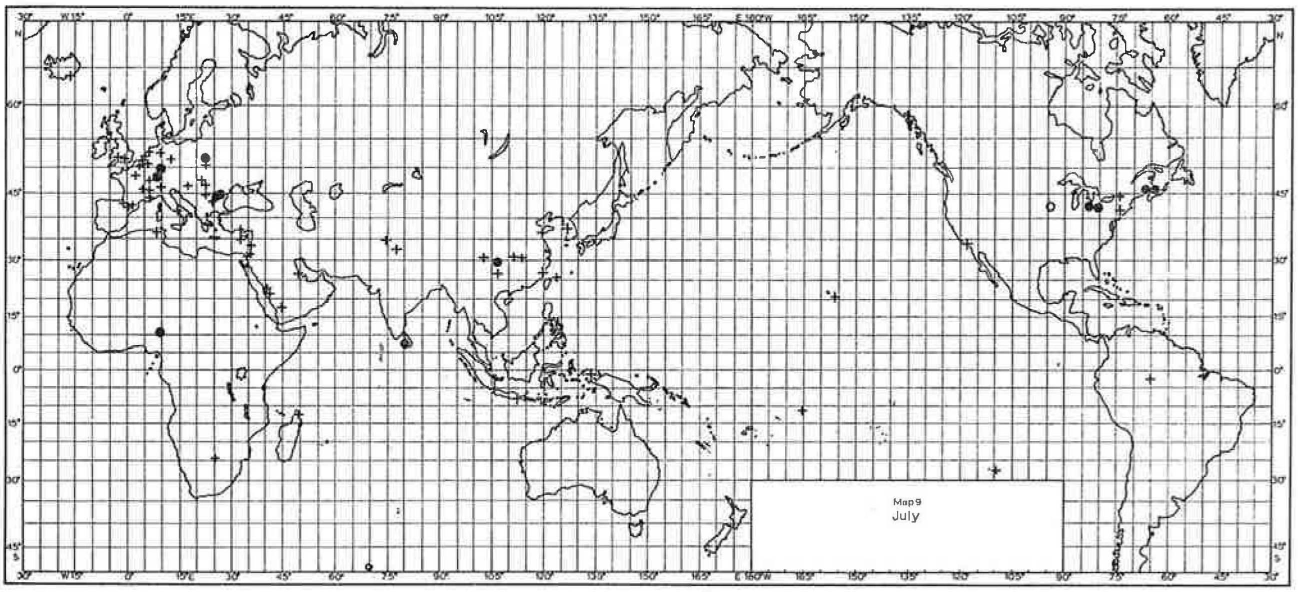

Map 4
February

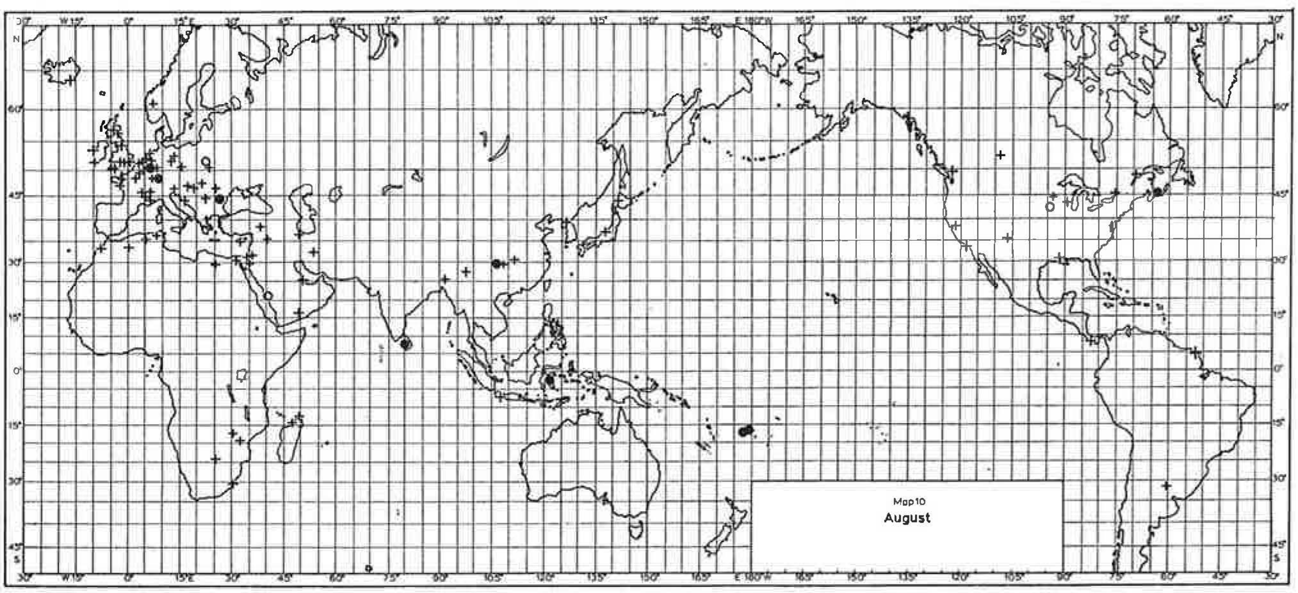

Map 5
March

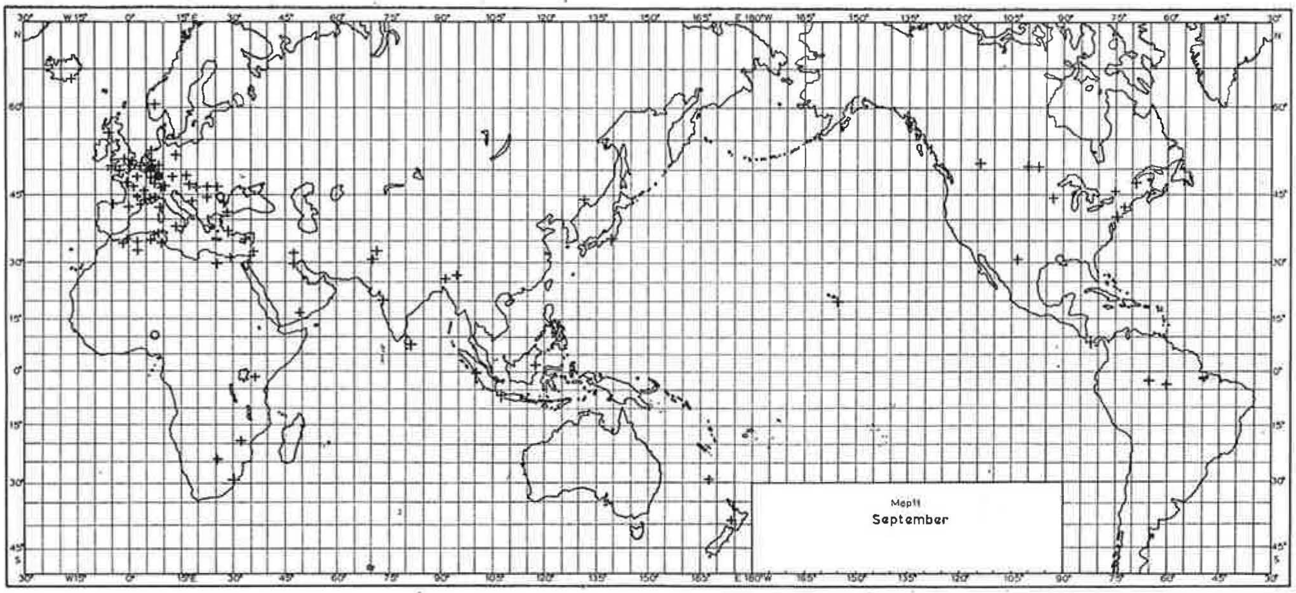

Map 6
April


Map 7
May

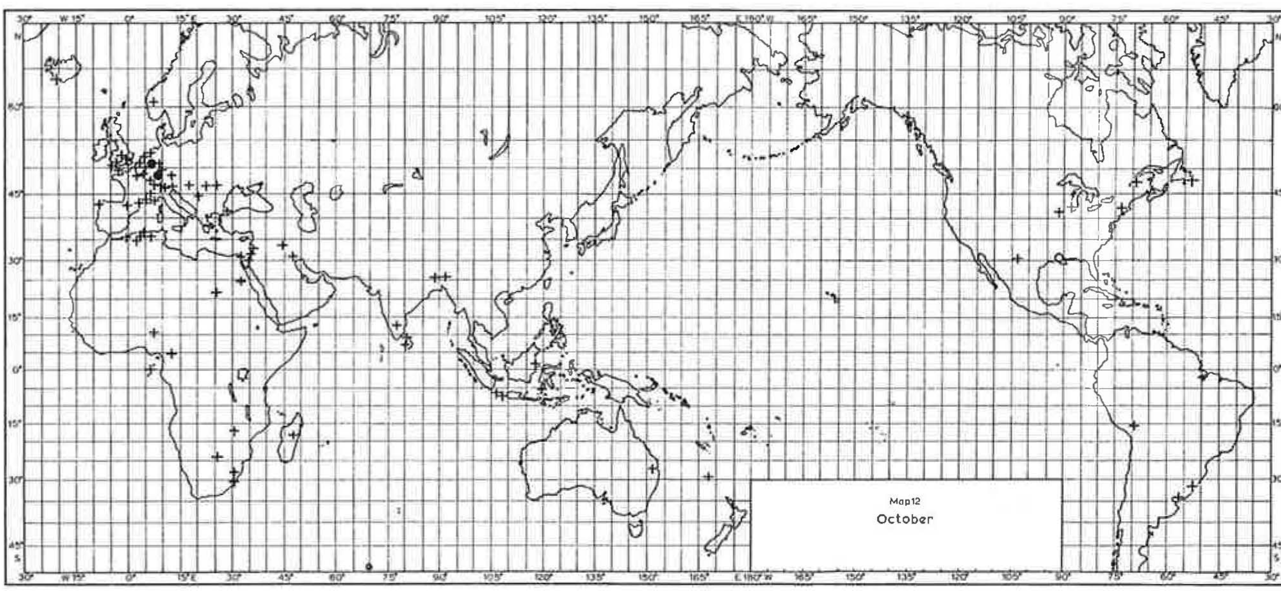

Map 8
June


Map 9
July

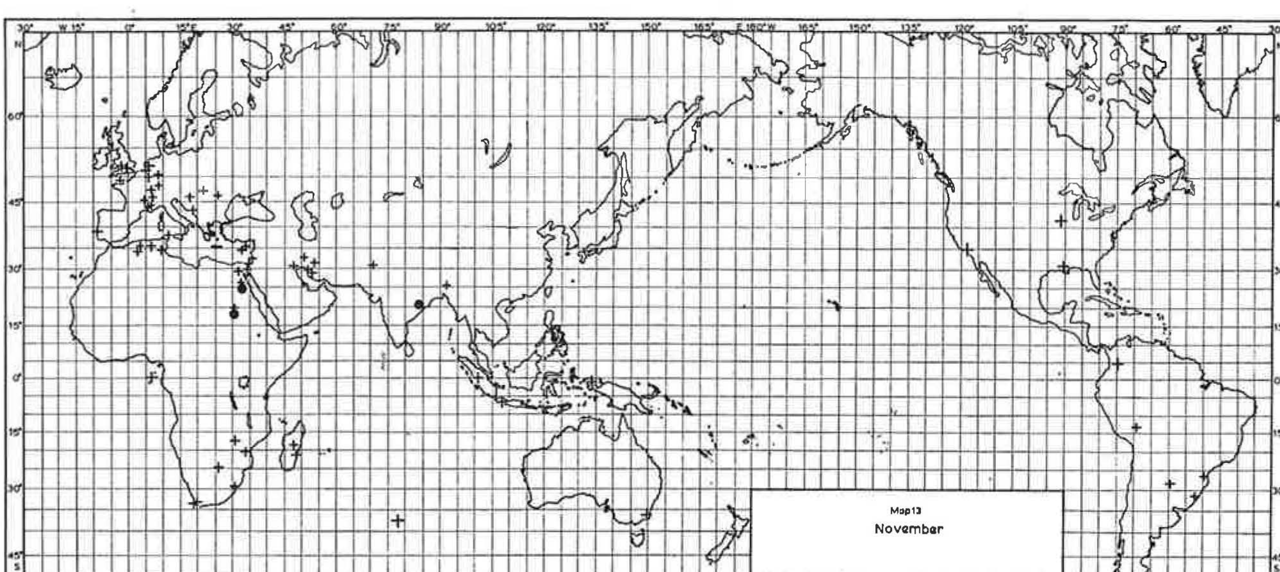

Map 10
August



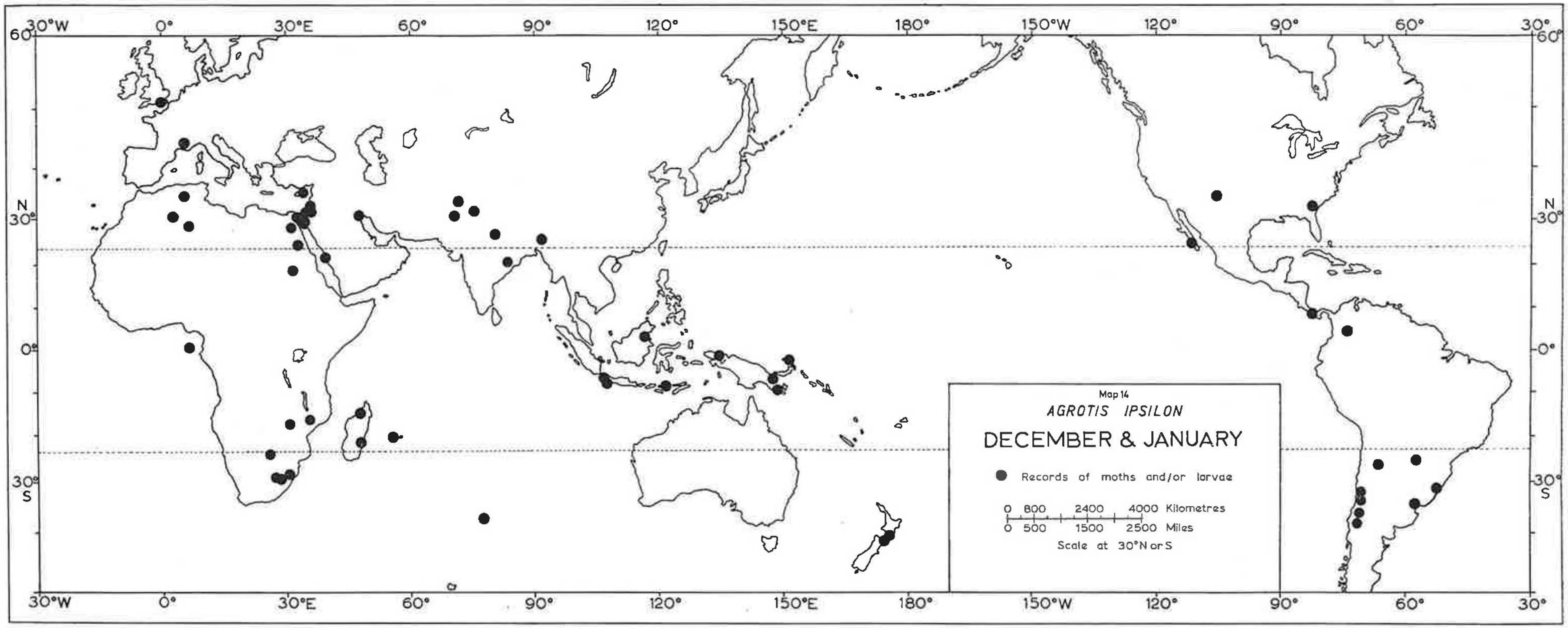
Map11
September

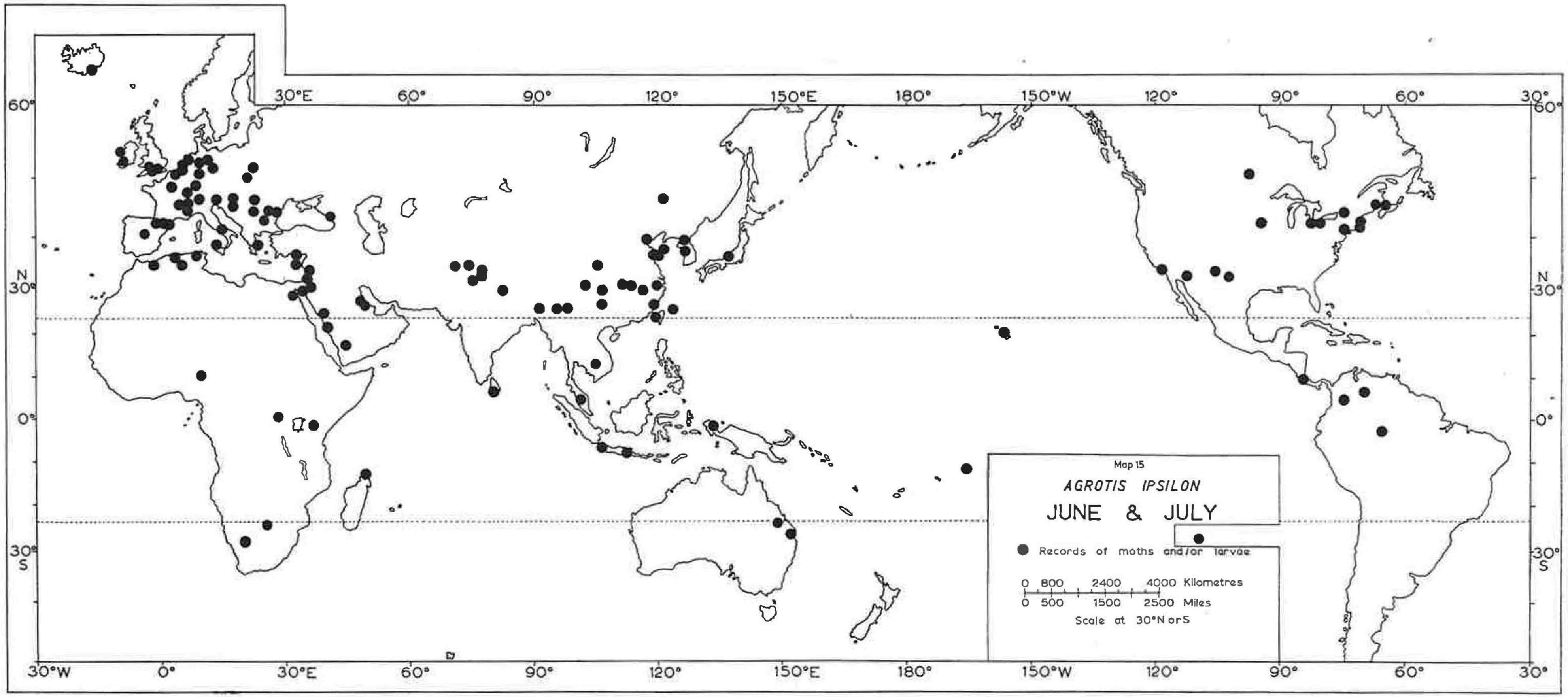


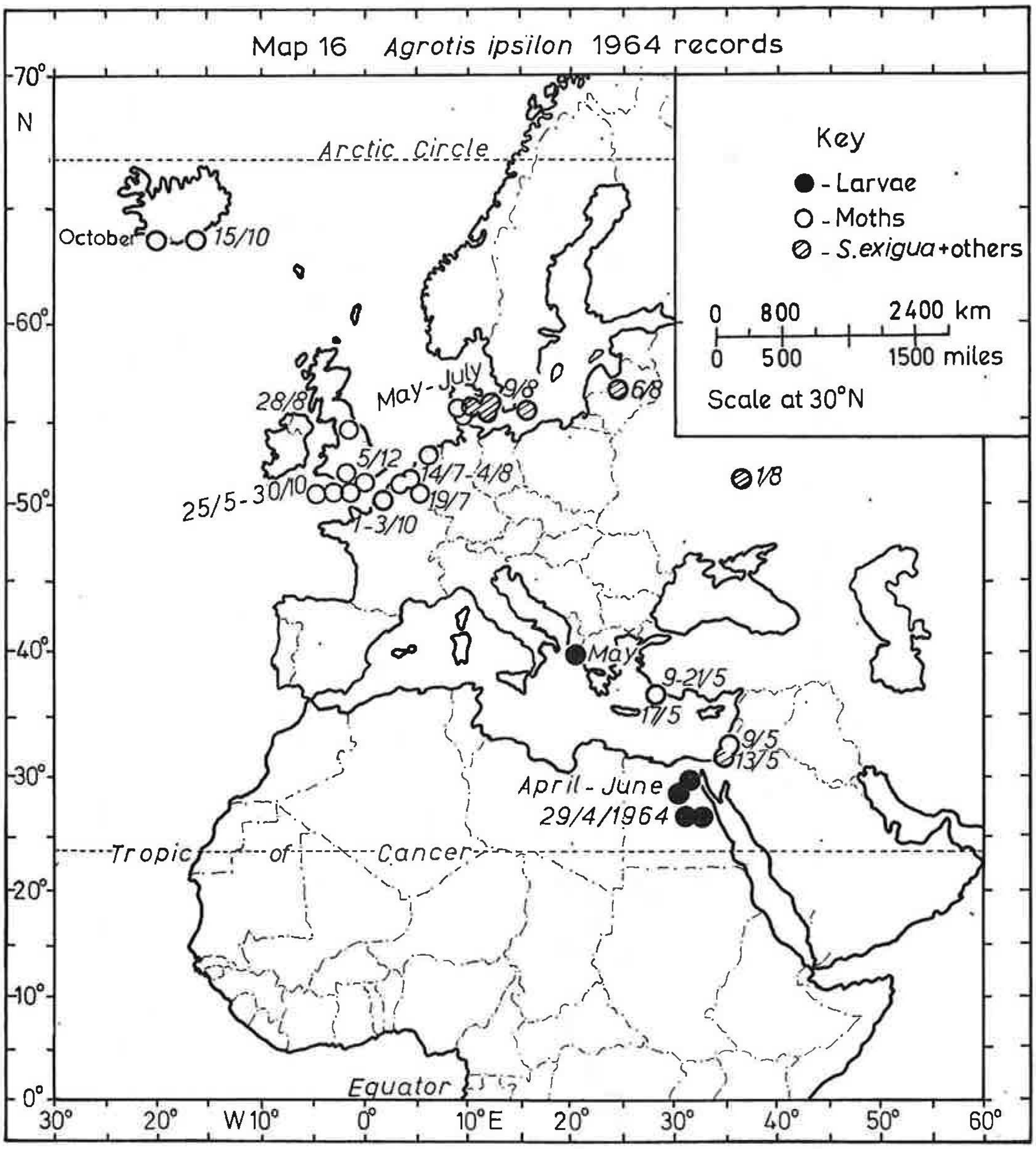
Map12
October



Map13
November


Map 14
AGROTIS IPSILON
DECEMBER & JANUARY
Records of moths and/or larvae
0 800 2400 4000 Kilometres
0 500 1500 2500 Miles
Scale at 30°N or S
30°W
0°
30°E
60°
90°
120°
150°E
180°
150°W
120°
90°
60°
30°
60°
N 30°
0°
30° S


Map 15
AGROTIS IPSILON
JUNE & JULY
Records of moths and/or larvae
0 800 2400 4000 Kilometres
0 500 1500 2500 Miles
Scale at 30°N or S
30°W
0°
30°E
60°
90°
120°
150°E
180°
150°W
120°
90°
60°
30°
60°
N 30°
0°
30° S


Map 16 Agrotis ipsilon 1964 records
Key
● - Larvae
○ - Moths
⊘ - S.exigua+others
0 800 2400 km
0 500 1500 miles
Scale at 30°N
Arctic Circle
Tropic of Cancer
Equator
October
15/10
28/8
May-July
9/8
6/8
5/12
14/7-4/8
19/7
25/5-30/10
1-3/10
1/8
May
9-21/5
17/5
9/5
13/5
April - June
29/4/1964
70° N
60°
50°
40°
30°
20°
10°
0°
30°
20°
W 10°
0°
10°E
20°
30°
40°
50°
60°

Publications of the Centre for Overseas Pest Research

The Centre for Overseas Pest Research will continue to publish, at irregular intervals, the two series formerly produced by the Anti-Locust Research Centre: *Anti-Locust Memoirs* devoted to biogeographical and bioclimatic papers illustrated by maps, and *Anti-Locust Bulletins* containing papers on all other aspects of locust and grasshopper research and control. A new series entitled *Tropical Pest Bulletins* will deal with pests other than locusts and grasshoppers. The Centre is now also responsible for the publication of the quarterly journal *PANS* (*Pest Articles and News Summaries*) and the *PANS Manuals*. These publications may be bought from the Centre for Overseas Pest Research, College House, Wrights Lane, London W8 5SJ, at the prices indicated. Cheques, etc., should be made payable to H.M. Paymaster General and crossed. They are also available in exchange for the publications of other establishments working in the same fields by arrangement with the Librarian. Copies are available free to government and educational establishments and research institutes in the developing countries eligible for British aid.

Anti-Locust Memoirs

No. 1. Z. WALOFF. Seasonal breeding and migrations of the Desert Locust (*Schistocerca gregaria* Forskål) in eastern Africa. 1946. 74 pp., 30 maps, 2 figs. (*Out of print.*)

2. V. MORANT. Migrations and breeding of the Red Locust (*Nomadacris septemfasciata* Serville) in Africa, 1927–1945. 1947. 60 pp., 32 maps, 5 figs. (*Out of print.*)

3. U. DONNELLY. Seasonal breeding and migrations of the Desert Locust (*Schistocerca gregaria* Forskål) in western and north-western Africa. 1947. 43 pp., 19 maps, 1 fig. (*Out of print.*)

4. D. E. DAVIES. Seasonal breeding and migrations of the Desert Locust (*Schistocerca gregaria* Forskål) in north-eastern Africa and the Middle East. 1952. 57 pp., 13 maps, 2 figs. SBN 85135 010 0. *Price* 63p.

5. J. FORTESCUE-FOULKES. Seasonal breeding and migrations of the Desert Locust (*Schistocerca gregaria* Forskål) in south-western Asia. 1953. 36 pp., 14 maps, 1 fig. SBN 85135 015 1. *Price* 50p.

6. E. BETTS. Outbreaks of the African Migratory Locust (*Locusta migratoria migratorioides* R. & F.) since 1871. 1961. 25 pp., 9 maps, 2 figs. SBN 85135 005 4. *Price* 37p.

7. R. C. RAINEY. Meteorology and the migration of Desert Locusts. Applications of synoptic meteorology in locust control. 1963. 115 pp., 3 pls., 24 figs. *Also issued as* WMO tech. Note no. 54 (WMO no. 138 TP. 64). *For sale only from the World Meteorological Organisation, Geneva, Switzerland,* price Sw. fr. 25.

8. Z. WALOFF. The upsurges and recessions of the Desert Locust plague; an historical survey. 1966. 111 pp., 94 maps, 7 figs. SBN 85135 041 0. *Price* £1·25.

9. G. POPOV and M. RATCLIFFE. The Sahelian Tree Locust *Anacridium melanorhodon* Walker. 1968. 45 pp., 29 maps, 17 figs. SBN 85135 044 5. *Price* 53p.

10. F. T. BULLEN. The distribution of the damage potential of the Desert Locust (*Schistocerca gregaria* Forsk.). 44 pp., 29 maps, 4 figs. SBN 85135 045 3. *Price* 53p.

11. J. I. MAGOR. Outbreaks of the Australian Plague Locust (*Chortoicetes terminifera* Walk.) during the seasons 1937 to 1962, with particular reference to rainfall. 1970. 39 pp., 36 maps, 3 figs. SBN 85135 002 X. *Price* 70p.

12. M. CASIMIR and R. C. BAMENT. An outbreak of the Australian Plague Locust, *Chortoicetes terminifera* (Walk.), during 1966–67 and the influence of weather on swarm flight. 1974. 27 pp., 5 maps, 7 figs. ISBN 0 85135 062 3. *Price* 65p.

Anti-Locust Bulletins

No. 1. B. P. UVAROV. Recent advances in acridology; anatomy and physiology of Acrididae. 1948. 75 pp., 21 figs. (*Out of print.*)

2. J. S. KENNEDY, M. AINSWORTH and B. A. TOMS. Laboratory studies on the spraying of locusts at rest and in flight. 1948. 64 pp., 11 figs. (*Out of print.*)

3. D. L. GUNN, F. C. PERRY, W. G. SEYMOUR, T. M. TELFORD, E. N. WRIGHT and D. YEO. Behaviour of the Desert Locust (*Schistocerca gregaria* Forskål) in Kenya in relation to aircraft spraying. 1948. 70 pp., 8 pls., 21 figs. (*Out of print.*)

4. D. L. GUNN, J. F. GRAHAM, E. C. JAQUES, F. C. PERRY, W. G. SEYMOUR, T. M. TELFORD, J. WARD, E. N. WRIGHT and D. YEO. Aircraft spraying against the Desert Locust (*Schistocerca gregaria* Forskål) in Kenya, 1945. 1948. 121 pp., 11 pls., 33 figs. (*Out of print.*)

5. H. B. JOHNSTON and D. R. BUXTON. Field observations on locusts in eastern Africa. 1949. 74 pp., 5 pls., 6 figs. SBN 85135 008 9. *Price* 40p.

6. M. J. NORRIS. Reproduction in the African Migratory Locust (*Locusta migratoria migratorioides* R. & F.) in relation to density and phase. 1950. 50 pp., 7 figs. SBN 85135 025 9. *Price* 15p.

7. P. E. ELLIS. The marching behaviour of hoppers of the African Migratory Locust (*Locusta migratoria migratorioides* R. & F.) in the laboratory. 1951. 48 pp., 32 figs. SBN 85135 012 7. *Price* 15p.

8. G. F. BURNETT. Field observations on the behaviour of the Red Locust (*Nomadacris septemfasciata* Serville) in the solitary phase. 1951. 36 pp., 8 figs. SBN 85135 006 2. *Price* 13p.

9. Z. WALOFF and R. C. RAINEY. Field studies on factors affecting the displacement of Desert Locust swarms in eastern Africa. R. C. RAINEY and Z. WALOFF. Flying locusts and convection currents. 1951. 72 pp., 9 figs. SBN 85135 042 9. *Price* 30p.

10. B. P. UVAROV, E. CHAPMAN, N. WALOFF and A. R. WATERSTON. Observations on the Moroccan Locust *Dociostaurus maroccanus* Thunberg) in Cyprus, 1950. 1951. 55 pp., 12 figs. SBN 85135 039 9. *Price* 37p.

11. R. J. V. JOYCE. The ecology of grasshoppers in East Central Sudan. 1952. 99pp., 34 figs. SBN 85135 019 4. *Price* 50p.

12. D. L. GUNN and P. HUNTER-JONES. Laboratory experiments on phase differences in locusts. D. E. DAVIES. Statistical analysis of data on the selection experiments. 1952. 37 pp., 5 figs. SBN 85135 017 8. *Price* 25p.

13. M. J. NORRIS. Reproduction in the Desert Locust (*Schistocerca gregaria* Forskål) in relation to density and phase. 1952. 51 pp., 8 figs. SBN 85135 026 7. *Price* 37p.

14. G. POPOV. Investigations of suspected outbreak areas of the Desert Locust (*Schistocerca gregaria* Forskål) in Iran. 1953. 32 pp., 3 maps, 16 figs. SBN 85135 030 5. *Price* 27p.

15. O. W. RICHARDS. The study of the numbers of the Red Locust (*Nomadacris septemfasciata* Serville). 1953. 31 pp. 4 figs. SBN 85135 032 1. *Price* 20p.

16. V. M. DIRSH. Morphometrical studies on phases of the Desert Locust (*Schistocerca gregaria* Forskål). 1953. 34 pp., 31 figs. ISBN 0 85135 066 6. *Price* 25p.

17. O. W. RICHARDS and N. WALOFF. Studies on the biology and population dynamics of British grasshoppers. 1954. 182 pp., 67 figs. SBN 85135 034 8. *Price* £1·63.

18. M. J. NORRIS. Sexual maturation in the Desert Locust (*Schistocerca gregaria* Forskål) with special reference to the effects of grouping. 1954. 44 pp., 2 figs. SBN 85135 028 3. *Price* 23p.

19. R. F. CHAPMAN. A laboratory study of roosting behaviour in hoppers of the African Migratory Locust (*Locusta migratoria migratorioides* R. & F.). 1955. 40 pp., 26 figs. SBN 85135 007 0. *Price* 23p.

20. D. F. VESEY-FITZGERALD. The vegetation of the outbreak areas of the Red Locust (*Nomadacris septemfasciata* Serv.) in Tanganyika and Northern Rhodesia. 1955. 31 pp., 12 figs. SBN 85135 014 3. *Price* 17p.

21. K. M. GUICHARD. Habitats of the Desert Locust (*Schistocerca gregaria* Forskål) in western Libya and Tibesti. 1955. 33 pp., 24 figs. SBN 85135 016 X. *Price* 25p.

22. J. T. DAVEY and H. B. JOHNSTON. The African Migratory Locust (*Locusta migratoria migratorioides* R. & F.) in Nigeria. 1956. 91 pp., 26 figs. SBN 85135 009 7. *Price* 43p.

23. F. O. ALBRECHT. The anatomy of the Red Locust (*Nomadacris septemfasciata* Serville). 1956. 9 pp., 97 figs. ISBN 0 85135 067 4. *Price* 27p.

24. B. NICKERSON. Pigmentation of hoppers of the Desert Locust (*Schistocerca gregaria* Forskål) in relation to phase coloration. 1956. 34 pp., 7 figs. SBN 85135 023 2. *Price* 20p.

25. P. E. ELLIS and C. ASHALL. Field studies in diurnal behaviour, movement and aggregation in the Desert Locust (*Schistocerca gregaria* Forskål). 1957. 94 pp., 44 figs. SBN 85135 013 5. *Price* 53p.

26. R. C. RAINEY, Z. WALOFF and G. F. BURNETT. The behaviour of the Red Locust (*Nomadacris septemfasciata* Serville) in relation to the topography, meteorology and vegetation of the Rukwa rift valley, Tanganyika. 1957. 96 pp., 24 figs. SBN 85135 031 3. *Price* 57p.

27. J. P. DEMPSTER. The population dynamics of the Moroccan Locust (*Dociostaurus maroccanus* Thunb.) in Cyprus. 1957. 60 pp., 27 figs. SBN 85135 011 9. *Price* 37p.

28. M. J. NORRIS. Factors affecting the rate of sexual maturation of the Desert Locust (*Schistocerca gregaria* Forskål) in the laboratory. 1957. 26 pp., 2 figs. SBN 85135 024 0. *Price* 15p.

29. P. HUNTER-JONES. Laboratory studies on the inheritance of phase characters in locusts. 1958. 32 pp., 6 figs. SBN 85135 018 6. *Price* 17p.

30. W. J. STOWER, G. B. POPOV and D. J. GREATHEAD. Oviposition behaviour and egg mortality of the Desert Locust (*Schistocerca gregaria* Forskål) on the coast of Eritrea. 1958. 33 pp., 17 figs. SBN 85135 037 2. *Price* 35p.

31. G. B. POPOV. Ecological studies on oviposition by swarms of the Desert Locust (*Schistocerca gregaria* Forskål) in Eastern Africa. 1958. 70 pp., 51 figs. SBN 85135 029 1. *Price* 75p.

32. W. J. STOWER. The colour patterns of hoppers of the Desert Locust (*Schistocerca gregaria* Forskål). 1959. 75 pp., 17 tables, 5 col. pls., 24 figs. SBN 85135 036 4. *Price* £2·25.

33. R. F. CHAPMAN. Field observations of the behaviour of hoppers of the Red Locust (*Nomadacris septemfasciata* Serville). 1959. 51 pp., 27 figs. SBN 85135 043 7. *Price* 47p.

34. L. F. H. MERTON. Studies in the ecology of the Moroccan Locust (*Dociostaurus maroccanus* Thunberg) in Cyprus. 1959. 123 pp., 44 figs. SBN 85135 022 4. *Price* £1·00.

35. J. H. LLOYD. Operational research on preventive control of the Red Locust (*Nomadacris septemfasciata* Serville) by insecticides. 1959. 65 pp., 16 figs. SBN 85135 020 8. *Price* 53p.

36. M. J. NORRIS. Reproduction in the Red Locust (*Nomadacris septemfasciata* Serville) in the laboratory. 1959. 46 pp., 3 figs. SBN 85135 027 5. *Price* 37p.

37. L. H. F. MERTON. The Moroccan Locust (*Dociostaurus maroccanus* Thunberg) in Iran. 1961. 66 pp., 12 figs. SBN 85135 021 6. *Price* 45p.

38. C. ASHALL and P. E. ELLIS. Studies on numbers and mortality in field populations of the Desert Locust (*Schistocerca gregaria* Forskål). 1962. 59 pp., 17 figs. SBN 85135 004 6. *Price* 65p.

39. J. ROFFEY. Observations on night flight in the Desert Locust (*Schistocerca gregaria* Forskål). 1963. 32 pp., 9 figs. SBN 85135 033 X. *Price* 43p.

40. Z. WALOFF. Field studies on solitary and *transiens* Desert Locusts in the Red Sea area. 1963. 93 pp., 28 figs. SBN 85135 040 2. *Price* £1·13.

41. A. SHULOV and M. P. PENER. Studies on the development of eggs of the Desert Locust (*Schistocerca gregaria* Forskål) and its interruption under particular conditions of humidity. 1963. 59 pp., 11 figs. SBN 85135 035 6. *Price* 70p.

42. J. G. THOMAS. The abdomen of the female Desert Locust (*Schistocerca gregaria* Forskål) with special reference to the sense organs. 1964. 19 pp., 45 figs. SBN 85135 038 0. *Price* 43p.

43. M. J. NORRIS. Laboratory experiments on oviposition responses of the Desert Locust (*Schistocerca gregaria* Forskål). 1968. 47 pp. SBN 85135 046 1. *Price* 43p.

44. D. P. CLARK, C. ASHALL, Z. WALOFF and L. CHINNICK. Field studies on the Australian Plague Locust in the Channel Country of Queensland. 1969. 121 pp., 31 figs. SBN 85135 047 X. *Price* £1·25.

45. K. WARDHAUGH, Y. ASHOUR, A. O. IBRAHIM, A. M. KHAN and M. BASSONBOL. Experiments on the incubation and hopper development periods of the Desert Locust (*Schistocerca gregaria* Forskål) in Saudi Arabia. 1969. 38 pp., 16 figs. SBN 85135 048 8. *Price* 73p.

46. C. F. HEMMING and P. M. SYMMONS. The germination and growth of *Schouwia purpurea* (Forsk.) Schweinf. and its role as a habitat of the Desert Locust. 1969. 38 pp., 14 figs. SBN 85135 054 2. *Price* 53p.

47. C. H. FRASER ROWELL. Environmental control of colouration in an acridid, *Gastrimargus africanus* (Saussure). 1970. 48 pp., 1 col. pl., 5 figs. SBN 85135 000 3. *Price* 95p.

48. A. SHULOV. The development of eggs of the Red Locust, *Nomadacris septemfasciata* (Serv.), and the African Migratory Locust, *Locusta migratoria migratorioides* (R. & F.) and its interruption under particular conditions of humidity. 1970. 22 pp., 3 figs. SBN 85135 001 1. *Price* 50p.

49. R. D. MacCUAIG and M. N. D. B. YEATES. Theoretical studies on the efficiency of insecticidal sprays for the control of flying locust swarms. 1972. 34 pp., 13 figs. SBN 85135 057 7. *Price* 95p.

50. L. V. BENNETT and P. M. SYMMONS. A review of estimates of the effectiveness of certain control techniques and insecticides against the Desert Locust. 1972. 15 pp. SBN 85135 060 7. *Price* 50p.

Tropical Pest Bulletins

No. 1. J. I. MAGOR and P. WARD. Illustrated descriptions, distribution maps and bibliography of the species of *Quelea* (weaver-birds: Ploceidae). 1972. 20 pp., 2 col. pls., 3 maps. SBN 85135 058 5. *Price* £1·00.

2. E. JUDENKO. Analytical method for assessing yield losses caused by pests on cereal crops with and without pesticides. 1973. 31 pp. ISBN 0 85135 061 5. *Price* 40p.

3. R. M. C. WILLIAMS. Evaluation of field and laboratory methods for testing termite resistance of timber and building materials in Ghana, with relevant biological studies. 1973. 64 pp., 19 pls., 4 figs. ISBN 0 85135 065 8. *Price* £1·85.

4. P. O. ODIYO. Seasonal distribution and migrations of *Agrotis ipsilon* (Hufnagel) (Lepidoptera, Noctuidae). 1975. 22 pp., 16 maps. ISBN 0 85135 070 4. *Price* 75p.

PANS (Pest Articles and News Summaries)

PANS is published as a quarterly journal to keep workers in the developing countries informed of the latest advances in all aspects of crop protection. The subscription rate for PANS is £3·00 per annum post free by surface mail or £1·00 for individual numbers supplied separately. The air mail subscription rate is £9·00 per annum.

PANS Manuals

PANS Manuals are a series of handbooks, each one dealing with all aspects of pest control in a single tropical crop. The aim is to inform workers directly concerned of the most recent techniques in crop protection.

PANS Manual No. 1 Pest Control in Bananas. SBN 85135 059 3. *Price* 42p.

PANS Manual No. 2 Pest Control in Groundnuts. ISBN 0 85135 063 1. *Price* 50p.

PANS Manual No. 3 Pest Control in Rice. ISBN 0 85135 068 2. *Price* 62p.

The following publications may also be purchased:

The locust handbook. London, Anti-Locust Research Centre. 1966. Loose-leaf, illus. SBN 85135 053 4. *Price* £3·37. (Supplements, when ready, *gratis.*)

Report of the Anti-Locust Research Centre for 1967. 1968. 36 pp., illus. *Price* 35p.

Report of the Anti-Locust Research for 1968. 1969. 45 pp., illus. *Price* 35p.

Report of the Anti-Locust Research Centre for 1969. 1970. 49 pp., illus. *Price* 35p.

Report of the Anti-Locust Research Centre for 1970–1971. 1973. 74 pp., illus. ISBN 0 85135 052 6. *Price* 62p.

Report of the Centre for Overseas Pest Research, June 1971–December 1972. 1973. 148 pp., illus. ISBN 0 85135 064 X. *Price* 62p.

Proceedings of the International Study Conference on the Current and Future Problems of Acridology, London 1970. Hemming, C. F. & Taylor, T. H. C. (Eds.). London, Centre for Overseas Pest Research. 1972. 524 pp., 107 figs. SBN 85135 003 8. *Price* £9·50 plus packing and postage 50p (surface mail) (cheques to be made payable to the Centre for Overseas Pest Research).

The following books are now available only from COPR and not from booksellers as previously:

V. M. DIRSH. *The African genera of Acridoidea.* Published for the Anti-Locust Research Centre. Cambridge, at the University Press. 1965. xiii+579 pp., 452 figs. ISBN 0 521 04837 0. *Price* £12·00 ($35·00).

H. B. JOHNSTON. *Annotated catalogue of African grasshoppers.* Published for the Anti-Locust Research Centre. Cambridge, at the University Press. 1956. xxii+834 pp. ISBN 0 521 05442 7. *Price* £15·00 ($45·00).

H. B. JOHNSTON. *Annotated catalogue of African grasshoppers; Supplement.* Published for the Anti-Locust Research Centre. Cambridge, at the University Press. 1968. 528 pp. ISBN 0 521 05443 5. *Price* £9·00 ($25·00).

B. (P.) UVAROV. *Grasshoppers and locusts. A handbook of general acridology. Volume 1; Anatomy, physiology, development, phase polymorphism, introduction to taxonomy.* Published for the Anti-Locust Research Centre. Cambridge, at the University Press. 1966. xi+481 pp., 2 pls. (1 col.), 245 figs. ISBN 0 521 06669 7. *Price* £5·60 (*c.* $20·00). (*Volume II* in preparation.)

The following publications may be obtained free of charge:

The Centre for Overseas Pest Research: Organisation and projects. 1975. 12pp.

C. F. HEMMING. *The locust menace.* Revised edition 1974. 28 pp., illus.

P. HUNTER-JONES. *Rearing and breeding locusts in the laboratory.* 1966. 12 pp., 8 figs.

In Memoriam – Sir Boris Uvarov KCMG, FRS, 1888–1970. 1970. 19+29 pp.

Current Research on Orthoptera. 1970 (with 1972 Supplement). (The names and addresses of over 700 research workers from 66 countries, listed together with their research interests classified under eight subject headings.)

COPR Miscellaneous Reports

No. 1. W. J. KING and D. R. JOHNSTONE. *A modified microburette for the production of very small liquid droplets.* 1971. 6 pp.

2. I. A. D. ROBERTSON and P. HUNTER-JONES. *The grasshopper problem in Barbados.* 1971. 11 pp.

3. G. B. POPOV. *Outbreak of the African Migratory Locust in the Bornu Province of NE Nigeria, October – November 1970.* 1972. 7 pp.

4. D. G. CAMPION. *Some observations on the use of pheromone traps as a survey tool for* Spodoptera littoralis. 1972. 10 pp.

5. I. A. D. ROBERTSON. *Records of insects taken at light traps in Tanzania. I – The effect of moonlight on catches of* Belostomatidae (*Hemiptera: Heteroptera*). 1972. 8 pp.

6. E. G. HARRIS and J. E. H. GROSE. *Toxicities of several insecticides by topical application to houseflies and stable-flies.* 1972. 4 pp.

7. D. R. JOHNSTONE, K. A. HUNTINGTON and W. J. KING. *Battery-operated ultra-low-volume hand sprayers. Part 1. Effect of voltage variation on droplet size characteristics. Part 2. Discharge characteristics and service life of batteries.* 1973. 10 pp.

8. W. S. WATTS and M. ALAM. *Spray trials against the citrus blackfly* (Aleurocanthus woglumi) *on limes in the Oman.* 1973. 7 pp.

9. W. J. KING and D. R. JOHNSTONE. *Papers for sampling spray deposits of ultra-low-volume carrier solvents.* 1973. 7 pp.

10. A. H. COSENS and G. CALLOW. *A locust flight balance.* 1973. 8 pp.

11. E. G. HARRIS, J. E. H. GROSE and V. WESTON. *Breeding and handling the stablefly,* Stomoxys calcitrans *L.* 1973. 9 pp.

12. G. G. POPE and W. J. KING. *Spray trials against the Red-Billed Quelea* (Quelea quelea) *in Tanzania.* 1973. 3 pp.

13. M. N. D. B. YEATES. *Toxicity tests of various insecticides against the African armyworm,* Spodoptera exempta (*Walk.*), *East Africa 1969–71. Part 1. Laboratory tests. Part 2. Field trials.* 1973. 10 pp.

14. K. A. HUNTINGTON and D. R. JOHNSTONE. *A remote-recording field installation for monitoring micrometeorological variables during spray trials.* 1973. 12 pp.

15. K. A. HUNTINGTON and D. R. JOHNSTONE. *Cost comparison of methods of hand spraying of cotton in Malawi.* 1973. 10 pp.

16. D. J. McKINLEY. *An attempt to develop a completely artifical diet for rearing the Red Bollworm,* Diparopsis castanea. 1974. 4 pp.

Note

This list of publications was the most up-to-date available at the time of going to press. A current list may be obtained from the Librarian.