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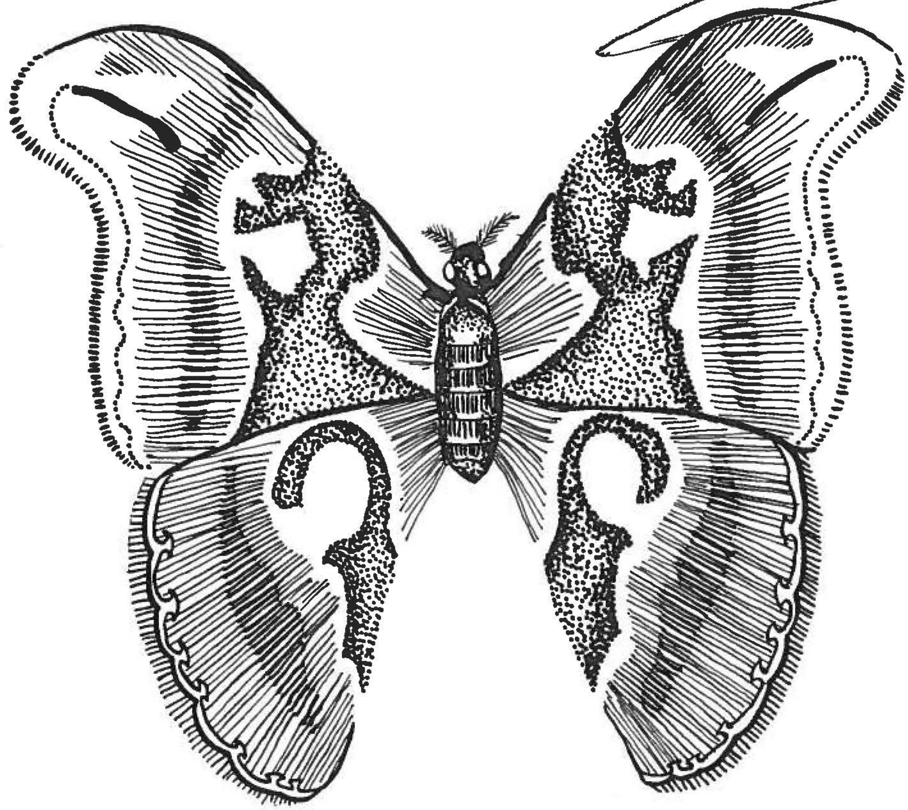
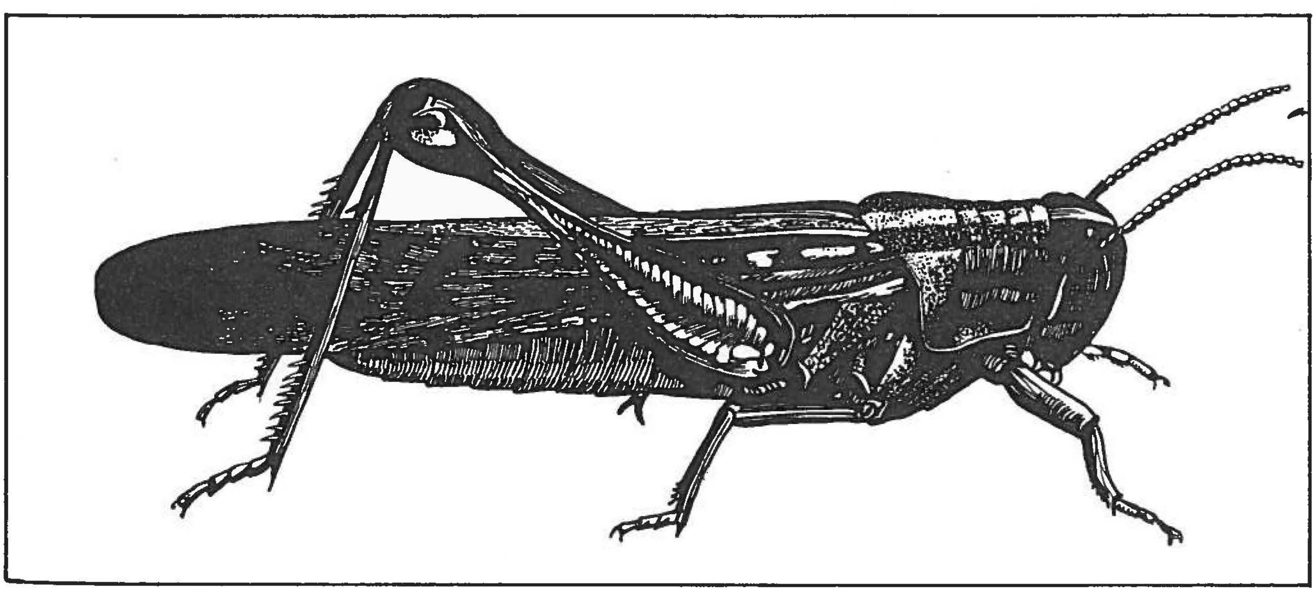


the manitoba ENTOMOLOGIST



THE MANITOBA ENTOMOLOGIST

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THE MANITOBA ENTOMOLOGIST

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THE MANITOBA ENTOMOLOGIST

An official publication of the Entomological Society of Manitoba, an organization to foster the advancement, exchange and dissemination of entomological knowledge

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THE MANITOBA ENTOMOLOGIST

CONTENTS (Continued)

IMPACT OF INSECT OUTBREAKS IN MANITOBA

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Invitational paper presented to the 20th annual meeting of the Entomological Society of Canada and the 26th annual meeting of the Entomological Society of Manitoba, August 24 - 26, 1970.

ABSTRACT

Manitoba's greater understanding of soil management after the dry years of the 1930's was followed by an improved policy of land use. Ultimately, land use planning was based on the land's capability for agriculture, forestry, recreation, and other activities. Changes in land use, especially replacement of native plants with agricultural crops, were accompanied by changes in the complex and abundance of insect pests. Outbreaks of agricultural insects have been more serious than forest insects from both the economic and sociological points of view, and grasshoppers have dominated all destructive species since establishment of this Province's first permanent settlement in 1812. In addition to economic losses, insect outbreaks have been partly responsible for migration of people from pest-prone communities to other rural and urban areas, and some migrants have experienced social difficulties after resettlement.

INTRODUCTION

The Province of Manitoba has undergone changes in name and shape over the last three centuries. Until 1870 it was part of other regions variously known as the ill-defined Rupert's Land, Assiniboia, and North West Territories. Boundaries have been redefined twice since 1870, so this discussion is largely confined to our present concept of Manitoba's land mass.

Although Manitoba has enjoyed a native culture for 35 centuries (18), its economic history dates only from the early days of the Hudson's Bay Company, which is celebrating its tricentennary this year (1970). Transition from a fur to an agricultural and forestry economy was accompanied by land use conflicts. These are reviewed in order to place major insect problems in proper perspective. Some of these insect problems, especially in agriculture, are intimately associated with conditions of soil, crop pathogens, weather, and market prices, as well as man's disturbance of the country's ecology since the beginning of colonization.

The economic and social significance of insect outbreaks can be expressed only in general terms, and many major pests are excluded from the discussion that follows because of a dearth of records.

LAND USE FOR AGRICULTURE AND FORESTRY

Agriculture

The Indians and early explorers utilized many native plants for food (16). Probably the most important of these was the service berry, *Amelanchier alnifolia* Nutt., which was used in the preparation of pemmican. Other favourite native plants included wild rice, *Zizania palustris* (sp.) [1] Hitche., in southeastern Manitoba, and wild turnip, probably *Psoralea*

[1] According to Dr. W.G. Dore, C.D.A., Ottawa, two varieties are common in eastern Manitoba. These are *palustris* and *interior*.

esculenta Pursh. These wild plants were gradually replaced with planted crops, although rice is still harvested for sale to gourmets.

According to Morton (24), the suitability of the Province's land for gardens was known as early as the late 1600's, when the first reported garden was planted by Nicholas Jeremie. The Hudson's Bay Company long encouraged gardening at their posts, even as far north as Churchill, but the suitability of the land for extensive farming was in doubt for many years. In 1720 La Noue reported that the country beyond Rainy Lake was one of extreme cold, and grain could not be grown to maturity. Contrary to La Noue's opinion, the Hudson's Bay Company in 1811 held the view that the interior of Rupert's Land was suitable for the cultivation of grain, and perhaps this opinion influenced the granting of all Assiniboia (116,500 sq. mi.) to Selkirk[1]. However, over four decades later the rights of the Company to the tenure of Rupert's Land beyond 1859 were challenged, and in 1857 the Company's governor, Sir George Simpson, gave testimony to the British Government in support of the extension, stating that the country was unfit for settlement (24). The controversy over agricultural suitability of the West and the need for sound government led to two noteworthy expeditions, both starting in 1857. One, led by Hind, a professor of chemistry and geology at Trinity College, was commissioned by the Canadian Government (35). The other, led by Palliser (25), was commissioned by the British Government. The two expeditions took place during a period of serious drought and high grasshopper populations. Their reports differed in detail but their conclusions were similar in some respects. Hind considered that agriculture was possible and Palliser believed that wheat growing would be precarious, especially in dry areas. In 1877, the Government of Canada commissioned John Macoun to write a comprehensive report on the Territories based on his several trips to the Plains. Macoun (19) concluded that parts of the country (including Manitoba) were indeed suitable for agriculture under favourable weather conditions.

The significance of Macoun's report was realized during the drought and grasshopper plagues of the 1930's. Although crop rotation was known as early as 1857 (13), and summer fallowing was practiced as early as 1889 (4), it took years of work and study by staff of the Experimental Farm Service, provincial departments of agriculture and the prairie universities before dry-land farming was understood. Aided by staff of the P.F.R.A. after its organization in 1935, it was demonstrated that intensive summer-fallowing on dry lands, instead of conserving moisture as previously thought, actually encouraged wind erosion, thereby destroying the fallow land on the leeward side (10). It was further determined that the best protection against soil drifting on summer-fallow was a rough soil surface. Instead of plowing, discing, and harrowing the soil intensively, it was learned that the soil should be cultivated only enough to keep down *excessive* weed growth (10), and the burning of stubble was discouraged.

The conclusions of the 1930's led to more diversification in farming and ultimately to land capability studies under terms of the Canada Land Inventory, which is concerned with capability of the land for agriculture, forestry, recreation, wildlife, and waterfowl.

Forestry

Preceding and during the early years of colonization, Indians commonly set prairie fires as a means of communication (4) and to encourage the growth of new grass as an enticement for buffalo to move into designated areas. Undoubtedly, these extensive and frequent fires restricted expansion of the aspen parkland. However, following the cessation of extensive prairie fiies, there is evidence that over a 50-year period from 1905 the parkland invaded the grassland to the south and closed gaps over large areas (4). Even the more northerly forests suffered extensive fire losses. Most of the early explorers commented

[1] This grant was made under fee simple, at a reported charge of 10 shillings (27).

on the widespread destruction caused by wild fires. Attempts to control such fires were insignificant until 1901, when the Canada Department of the Interior appointed 24 fire rangers to cover the Dominion forest lands of the three Prairie Provinces and interior of British Columbia. In 1930, Manitoba took over jurisdiction of all forest lands, within its boundaries except the Riding Mountain National Park. Two years later the Manitoba Government Air Service was organized around a nucleus of five pilots and five Vickers Veletes, purchased from the R.C.A.F. at one dollar each (2). The principal function of the service was fire patrol, but it wasn't until after the Second World War that Manitoba and the other Provinces had the technique and equipment capable of effectively suppressing forest fires.

Other forest management practices have also been improving. By 1943 it was noted by Ellis (8) that about 1,400,000 acres of impoverished farm lands would be suitable for developing community forests and woodlots, and planting on Crown lands accelerated after the last war. Simultaneously, increasing thought was devoted to the use of Manitoba's productive forest lands, which represent 6.1 percent of Canada's total[1]. Today the Crown forests of the Province are managed to satisfy demands for wood and recreation (20). Use of Manitoba's forested Crown lands is divided into three classes by Mair (20), as follows: (a) Lands under long-term timber lease with primary use being wood production and secondary use including hunting, fishing, and recreation (47,579 sq. mi.); (b) Management units and working circles with primary and secondary uses as in (a) (43,828 sq. mi.); and (c) Provincial parks where recreation is the primary use; in these parks hunting is restricted in built-up areas, fishing is permitted, and wood production is of secondary importance (2,817 sq. mi.).

IMPACT OF MAJOR OUTBREAKS

Agricultural Insects

Grasshoppers. Grasshoppers have been Manitoba's most destructive insect since the first reported outbreak in 1799. Information on outbreaks during the nineteenth century is fragmentary, but high populations occurred in parts of the Province during the following periods: 1799-1800; 1808; 1818-21; 1857-58; 1861; 1865-1867; and 1868-1875. During the present century to 1953, Manitoba experienced six severe outbreaks, each of which lasted four to six years, the most accurately documented dating from 1931 (23, 29) when Criddle was the first to organize formal surveys. The outbreak pattern after 1953 closely followed that of Saskatchewan where Riegert (28) reported a major outbreak from about 1957 to 1964. This outbreak peaked in 1963 when 61 percent of the agricultural area south of 53° 30′ north latitude was infested in Saskatchewan.

The above sequence of outbreaks conceals a remarkable succession of grasshopper species associated with a changing ecology. The most significant of these changes has been replacement of native vegetation with cultivation, drainage, and road building (6, 5). Succession of species, however, cannot always be satisfactorily explained. For example, *Melanoplus spretus* (Walsh) was a noxious species widely distributed over the western plains before 1900. Now extinct, the species was considered by Brooks (7) to have persisted in Canada for only one or two years after each invasion from the south. It has not been seen in this country since 1902.

It can be assumed that all the recorded grasshopper outbreaks caused untold economic losses and hardships. Economic losses undoubtedly intensified after 1876, when Manitoba first became a wheat exporting Province, but the epidemics of 1818-1821, 1857-1858, 1868-1875, and 1931-35 are worthy of special mention.

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[1] Can. Forestry Statistics 1966 - Dominion Bureau of Statistics, Ottawa

The 1818-1821 epidemic seriously affected the morale of Manitoba's first permanent settlement on the Red River, especially the "De Meurons". These settlers, mostly of German-Swiss origin, were former soldiers of Selkirk's De Meuron Regiment. They had served as mercenaries in the Napoleonic Wars and came to Canada in 1812 (27). Selkirk planned to enlist his old Regiment to settle in the Red River Settlement, thereby assuring a force for defence and food production. Most of the men returned to England soon after their arrival in Montreal, and of 84 that agreed to reside in the new Settlement, 64 soon left for the east. According to Pritchett (27) the remaining De Meurons were often mutinous, Sir George Simpson noting: "I should be rejoiced to see every Meuron in the colony away; they will never pay a farthing of their debts and are continually in distress". The frequent grasshopper epidemics were extremely disturbing, and as early as 1818, partly because of grasshoppers and other insects, the De Meurons were determined to leave. Actual departure did not occur until after the great flood of 1826, when about 300 settlers including the De Meurons emigrated to the Upper Mississippi (27).

The 1857-1858 epidemic was in full force when Hind (13) visited the country. He noted: "At the mouth of the little Souris River, grasshoppers in countless numbers and so voracious as to attack and destroy every article of clothing left for a few minutes on the grass. Saddles, girths, leather bags, and clothing of every description were devoured without distinction. Ten minutes sufficed them, as our half-breeds found to their cost, to destroy three pairs of woollen trousers which had carelessly been thrown on the grass".

Despite frequent grasshopper plagues, especially the epidemic of 1868-1875, settlers continued to flow into Manitoba during the last quarter of the nineteenth century. In 1875, settlements on the Whitemud River lost everything. In 1875 and 1876 loans for supplies and seed-grain were advanced by the Federal Government and the Provincial Agricultural Society (24). Nevertheless, immigrants in 1875 numbered 11,970 compared with 3,000 to 4,000 during the critical grasshopper years of 1873 and 1874 (24).

Undoubtedly, the epidemic of 1931-1935 was the most demoralizing in Manitoba's history because it was accompanied by low prices, drought, and rust. The drop in the price of wheat was critical in 1932 when Number 1 Northern fell to 40 cents per bushel at the Lakehead. Most wheat graded number 3 or 4, which sold five to 10 cents less than Number 1, and the freight to Fort William was about 15 to 20 cents per bushel (10). Despite these low prices, Manitobans continued to fight back against the grasshopper. In 1933, every dollar spent on grasshopper control protected grain with an estimated value of $57.00.[1] In 1934 crop losses from grasshoppers were estimated at 1,112,000 bushels of wheat and 4,501,000 bushels of oats and barley. Some 13,737 tons of bait, at a cost of $204,320 were used to save crops evaluated at $7,347,000 (40). The wheat yield during the 1930's (about 14 bu. per acre)[2] was only slightly less than during the 1920's (about 15 bu. per acre)[2] and considerably less than in the 1940's (about 29 bu. per acre)[2]. However, the 1930's differed markedly in that serious social disorders erupted from the combined effects of grasshoppers, drought, and underpriced, low-quality wheat.

The situation in 1931 led to a Red Cross appeal for destitute farm families, and the appeal was answered by arrival of 247 carloads of food and clothing, including one carload of dried cod (10). In some areas the farmers could scarcely find enough water to dissolve the salt in those bilious slabs of cod. Because the money supply inhibited the purchase of gasoline, automobiles were often converted to "Bennett buggies" by the ingenious farmers. By 1936, 700 families had moved from rural Manitoba to the cities and parkland, and 200,000 acres of land in the dust bowl of south-western Manitoba were vacated.

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1 Romanow, W. Unpublished data.

2 From Canada Year Books.

Riegert (28) noted that up to the turn of the present century, the people of Saskatchewan had an almost fatalistic attitude toward grasshopper epidemics, accepting and combatting them only at the peak of populations or when crops were threatened. Presumably Manitobans had the same attitude, but this attitude undoubtedly changed with the inauguration of organized control measures.

Wheat Stem Sawfly. Hind (12) in his prize-winning essay[1] on insects and diseases of wheat crops, noted that perhaps species of wheat stem sawflies had not been identified on this continent to 1857, but he was quite certain that numerous species would be found infesting wheat crops in America. Thirty-nine years later, the presence of *Cephus cinctus* (Nort.) in Manitoba was confirmed (4). The sawfly is a native insect that attacked certain native *(Agropyron)* grasses. It later adapted to wheat, becoming a major pest after 1900, especially from 1910 to 1925. During the years of sawfly outbreaks from southwestern Manitoba to the foothills of the Rockies, annual losses of wheat from sawfly attack were estimated at 50,000,000 bushels (3). Reductions of populations after 1925 were attributed to extensive plantings of partially resistant Durham wheat and to scarcity of susceptible grasses with large stems (4). Development of the resistant Rescue wheat (3) also significantly contributed to the decline of sawfly populations.

Sugar Beet Insects. The first commercial production of sugar beets in Manitoba was in 1940 when the factory of the Manitoba Sugar Company opened. That year some 15,600 acres of sugar beets were harvested, and the acreage peaked in 1969 at 29,000 acres.

Sugar beets in the western prairies are attacked by at least 14 major insect pests of which flea beetles, root maggots, and a webworm are among the most important (34). The impact of these insects on Manitoba's crop has not been well documented but in Alberta, which has a longer history of sugar beet culture, loss of the sugar beet crops in 1955 was estimated at 5 percent. If this degree of loss could be applied to Manitoba's crop, one could estimate that this Province lost about 12,000 tons from insect attack in 1966.

Sunflower Insects. Sunflower production is another new industry in Manitoba, having started in 1942. It naturally follows that only limited historical information on pests of this crop has accumulated, but it is known that five species of sunflower insects are capable of causing damage periodically (39). The most important species is *Phalonia hospes* Wlshm., which can destroy up to 7.5 percent of the seeds. A loss of this magnitude, when the Province's production is over 39 million pounds[2], is significant considering that Manitoba is Canada's largest producer of sunflower seeds and the value of the crop from 1955 to 1966 was only about $27.00 to $41.00 per acre.

Stored Grain Insects and Mites. The abundance and species composition of stored grain insects are intimately associated with storage conditions such as excessive moisture, sanitary care before stockpiling, or, especially in the case of mites, length of period in storage.

Some 17 species of insects and 14 of mites are associated with "hot spots" in farm-stored grain (32), the most abundant insect and mite being the rusty grain beetle, *Cryptolestes ferrugineus* Steph., and the long-haired mite, *Glycyphagus destructor* Schr., respectively. The most common insect in bulk storage in Manitoba is *Lathridius minutus* L., whose numbers and size of colonies vary with degree of premature germination.

It is questionable if one can separate economic losses caused by insects and mites of stored grain from those caused by other agencies. Annual losses of stored wheat in the

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1 Prize of £40 was awarded by the Canada Bureau of Agriculture and Statistics.

2 Canada Year Book 1968.

U.S.A., have been estimated at 3 percent, but because of our colder climate, losses would be considerably less in Canada. Dr. I. Hlynka[1] believes that the loss might be less than 1 percent in Manitoba. Even a fractional loss could be significant during a period of low sales in Manitoba where wheat in storage at the beginning of 1970 totalled about 77,500,000 bushels[2].

Insects of Wild Rice. Possibly the first impact of crop insects was felt in southeastern Manitoba, where failure of wild rice crops was occasionally reported. However, evidence of insect involvement is largely circumstantial. In his attempt to establish posts between Lake Superior and Lake Winnipeg, La Verendrye encouraged local bands of Indians to supplement food supplies with wild rice for sale to the voyageurs. Development of this trade route was slow, partly because of fear of dying from starvation (24). Food shortage was especially precarious in 1735 because high water was said to have damaged the rice crop. Again in 1838, the Indians were disappointed in their harvest of wild rice in the Rainy Lake area (Ontario) and had to depend more on their net fishing (9), but the cause of the rice failure was not indicated. Another rice failure occurred in 1857, Hind (13) noting that high water checked the growth of rice to an extent which, coupled with other deficiencies, threatened the Indians with famine. Although it is known that high water can indeed wipe out a wild rice crop, it has also been established that the combined feeding of six species of insects can be destructive (21). Insect damage in the Whiteshell area was especially high in 1957 and moderately high in 1958. Collapse of the outbreak in 1959 was thought to have been caused by high water levels (21), but the high water also reduced the rice crop with the harvest being about 5 percent of its 31-year average. It is probable that infested rice crops affected the food supplies of the Indians and voyageurs during the period of exploration in Manitoba. From 1934 to 1968, Manitoba's annual harvest of wild rice from lands excluding Indian reserves has averaged about 119 thousand pounds, peaking in 1967 at 593 thousand pounds. Crop failure, or near failure, occurred 5 times over the 35-year period. Although crop reductions from high water or insects may not appear to be catastrophic, they are nevertheless significant considering that the crop is harvested largely by the indigenous population under government management.

Insects Affecting Man and Animals

The nature of problems and research associated with insects of man and animals to 1956 was reviewed by Twinn (37), with emphasis on cattle warbles, horse bots, ticks, and biting flies. One of the most interesting problems is the relationship between mosquitoes and Western Encephalitis (W.E.) because both man and animals are affected. This relationship has been the subject of considerable study by the University of Saskatchewan, University of Manitoba, Manitoba Department of Health, and Canada Department of Agriculture. These studies have revealed evidence of the midsummer infection chain[3] from which man and horses become infected, and work is continuing on the connecting link between the overwintering reservoir and the midsummer infection chain.

As noted by MacKay *et al* (17), before an epidemic of W.E. can occur there must be a susceptible host population, a reservoir of the virus must be available for the mosquito, and a sufficient number of mosquitoes must be present to transmit the infection in epidemic proportions. There is evidence that at least seven species of mosquitoes belonging to the genera *Culex*, *Aedes*, and *Culiseta* serve as vectors of W.E., but the proportion of these species may vary considerably from year to year. The abundance of some species may show a strong correlation with summer precipitation or with mean weekly temperatures.

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1 McLintock, J., A.N. Burton, and J.R. Rempel. Unpublished manuscript.

2 Hiscocks, G.A. C.D.A. Personal communication.
40 million bu. on farms; 33 million bu. in line elevators; and 4.5 million bu. in terminal elevator at Churchill.

3 McLintock, J., A.N. Burton, and J.R. Rempel. Unpublished manuscript.

Epidemics of W.E. in Manitoba have been reported periodically, 1919-1920, 1926, 1941, and 1964. In 1941, 509 human cases were known in Manitoba, 78 resulting in death (15). There were no known cases in 1965 or 1966. The incidence of equine W.E. and horse populations have been showing a downward trend except where unusual, local situations prevail. Between 1954 and 1966, Manitoba's horse inventory dropped from 87,000 to 34,000 but in 1968 the number increased to 38,000 undoubtedly due to a brisk demand for estrogen or allied chemicals in Brandon. This demand was met by means of the "Pregnant Mares' Urine" program, and 109 participating farmers grossed $1,290,000 from 3,100 mares in 1968. It is feared by some that this concentration of horses in the Brandon area will favour a new outbreak of W.E. However, this fear is probably over-ridden by the uplift of new wealth and by a sense of security attending that new equine byproduct usually known as "the pill".

Manitoba is unique in that about half its population benefits from anti-mosquito programs of a single organization — the Mosquito Abatement Branch, Metropolitan Corporation of Greater Winnipeg. The program is financed through property taxes (3) and the Branch is responsible for mosquito control on an area of 256 square miles supporting a population of 500,000. In addition to control operations, the Branch monitors the efficiency of these operations by means of strategically located light traps, and new materials are tested annually. The small levy for the control program is probably infinitesmal in relation to the peace of mind gained from removal of the mosquito scourge.

Forest Insects

Jack Pine Budworm. Forest insect outbreaks have been under annual surveillance since the beginning of the Forest Insect and Disease Survey in 1937. One of the major pests reported during this period has been the jack pine budworm, *Choristoneura pinus pinus* Freeman, which attacks jack and Scots pine.

Defoliation of scattered natural stands over areas up to 1,700 square miles has been reported. Fortunately, infestation boundaries of individual stands within large outbreak areas tend to be flexible so trees are not often critically defoliated longer than three successive years during each outbreak. It has been shown by the Survey that two years of moderate to severe defoliation plus one year of light defoliation are capable of causing about 2 to 11 percent loss in basal area of trees in all diameter classes, and in the Sandilands Provincial Forest an outbreak caused 12 to 60 percent of jack pine tops to die. Severe defoliation causes appreciable increment reduction, which is greater in Scots pine than in jack pine.

It is doubtful if economic losses from this insect in Manitoba are significant, because the Province normally carries out salvage or presalvage operations in readily accessible areas. However, the budworm is often troublesome in recreation areas, where jack pine enjoys a high aesthetic value.

Spruce Budworm. The spruce budworm, *Choristoneura fumiferana* Clem., shows a rather different outbreak pattern in Manitoba as compared with Quebec and New Brunswick, probably because Manitoba does not have extensive, unbroken stands of susceptible tree species. Generally, the Manitoba outbreaks as recorded by the Survey, are of short duration; some, as in the Spruce Woods Provincial Forest, are restricted to white spruce and cause negligible damage.

The most exceptional outbreak since 1937 started as a localized infestation of 5,500 acres near Namew Lake in 1952. By 1965 an area of 1,500 square miles of scattered stands of spruce or balsam was affected, with an extension into Saskatchewan, and the outbreak persisted until 1969. Some of the "pockets" were severely defoliated, followed by varying degrees of mortality of white spruce and balsam fir. The economic loss from this outbreak was light, especially in Saskatchewan where an extensive salvage operation was conducted.

Forest Tent Caterpillar. The forest tent caterpillar is one of the most common insects of *Populus* in parkland forest and shelterbelt plantings. The insect has been common every year from 1923 (11), and undoubtedly much earlier, but cartographic records of annual infestations do not clearly show outbreak trends on the Prairies. Outbreaks in the early 1950's usually caused not more than two years of almost complete defoliation, followed by one of light to moderate. This level of defoliation was not sufficient to cause appreciable tree mortality, but it did cause an increment loss estimated at 8.4 percent of the basal area in scattered stands over an area totalling about one and a half million acres of aspen in Manitoba and Saskatchewan. Because of light demand for aspen in the area under observation, increment reduction in the 1950's cannot be considered as a significant economic loss. The insect, however, does rate high as a nuisance in recreation and tourist areas. Equally annoying are the swarms of sarcophagid flies associated with the declining phase of forest tent caterpillars outbreaks. Most tourists are convinced that these are biting flies and react accordingly.

Large Aspen Tortrix. Hind (13), during his exploration of the Prairies, commented "We entered the Bad Woods (Spruce Woods?), and followed the road cut by hunters in 1852. The aspens were much disfigured by countless numbers of caterpillars resembling those of the destructive Palmer Worm". The species we recognize as Palmer Worm today, *Dichomeris ligulella* Hbn., has been collected by the Survey mainly from basswood and oak, and outbreaks have not been reported in Manitoba in recent times. It is more likely that Hind witnessed the damage caused by the large aspen tortrix, *Archips conflictana* Wlk., which shows strong periodicity in population density according to the records of the Survey and Prentice (26). Unusually high populations occurred during the following periods or years: 1916-1917; 1946-1948; in the Duck Mountain area; 1948-1950 in The Pas area; 1957 in the interlake and Riding Mountain areas; 1959 in Riding Mountain; and 1966 to 1969, at many scattered points in the Province.

Twice during these outbreaks, scattered aspen stands were defoliated over areas of 10,000 square miles. Severe defoliation rarely lasts more than two years so mortality and increment loss are negligible, but the insect frequently causes concern near golf courses and other recreation areas.

White Grubs. Criddle worked on the white grub complex as early as 1914, but it was not until 1956 that the potential of white grubs as forest pests was fully recognized in Manitoba. That year the Manitoba Forest Service began an extensive afforestation program that was to cover some 70,000 acres of light soil in the Belair, Agassiz, Sandilands, and Whiteshell Provincial Forests. Failures following the first two years' planting showed the presence of several species of white grubs, *Phyllophaga drakei* (Kby.), *P. anxia* Lec., and *P. nitida* (Lec.) (14). Considerable sampling in the Agassiz Provincial Forest[1] showed a correlation between the number of grubs per cubic foot of soil (0.7 to 5) and the percentage mortality of transplants (15 to 84). In addition, from 15 to 30 percent of the living plants showed severe root damage. Because a grub population of 0.5 per cubic foot of soil is capable of causing damage, the Province abandoned some planting areas, rescheduled their program, and introduced chemical control measures. However, subsequent observations[2] and intensive sampling with mechanized equipment indicated that the white grub problem in plantations in the study area can be adequately met by planting only in years of low grub population.

Shelterbelt Insects

Shelterbelt plantings consist principally of caraganas, Manitoba maple, green ash, and white spruce. The principal pest of deciduous shelterbelts is the fall cankerworm, *Alsophila pometaria* Harr. Spruce shelterbelts are attacked by several pests, notably the pine needle scale, *Phenacaspis pinifoliae* Fitch, spruce spidermite, *Oligonychus ununguis* (Jacob), and the yellow-headed spruce sawfly, *Pikonema alaskensis* Roh. Attacks by these and other pests reduce the shelterbelt function of the infested trees, and premature death leads to replacement, which adds to the problem of farm labour.

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[1] Campbell, A.E., L.L. McDowall and R.M. Prentice. Unpublished data.

[2] Nairn, L.D. Unpublished data.

DISCUSSION

This review has focused attention on outbreaks of representative economic groups or species of insects, but many major pests were excluded because of inadequacy of records. It is evident that damage to agricultural crops in Manitoba has been higher, and less acceptable, than damage to forest crops. Furthermore, too many Canadian entomologists have not adequately publicized continuing records of losses from insect attack over the past 30 years. In contrast, the United States Department of Agriculture has estimated the annual losses of the principal agricultural and forest crops based on statistics of pest damge for the period 1951 to 1960 (8). Such estimates are useful in establishing priorities for research on insect ecology and control strategy, but admittedly they lack precision. In periods of overproduction, loss estimates may have different meanings to different people. For example, with Canada holding over one third of the world's surplus wheat, economists could argue, perhaps not realistically, that the grasshopper could be classed as a beneficial insect were it to devour Manitoba's entire 1970 wheat crop. Such destruction in company with a "soil bank" policy could appreciably shorten the period of wheat surplus. However, the soil bank could also theoretically produce a detrimental effect. If, for example, farmers choose to keep large acreages of the soil bank in fallow, there could be some risk of blowing of topsoil in dry areas. Because of complex situations of this sort, the term "losses" in this paper primarily refers to volume of food or fibre eaten or destroyed by insects. The references to monetary losses could be challenged by those familiar with the complex factors that affect crop prices and the influence of prices on the activities of producers and consumers.

Manitoba has undergone an endless cycle of settlement, migration, resettlement and migration - a cycle that was not confined to the depression of the 'thirties (10). However, migration from dry areas to more northerly farms and to urban communities was a phenomenon of the 'thirties, partly due to grasshopper outbreaks. In any explanation of migrations from farms it is difficult to separate the economic from the social and psychological factors (1). This difficulty is evident in an analysis of recent interviews with 100 former farm operators living in Saskatoon (1). Their migration was generally prompted by a desire for economic, social, and personal improvement. Many were searching for occupations with less anxiety and strain, and greater predictability of the results of their efforts. These goals have connotations of unhappy experiences involving the consequence of insect outbreaks. The study further suggests that discouraged rural migrants are likely to experience economic, social and psychological disadvantages in their new environment. It is therefore possible that catastrophic farm losses, whether from insects or other factors, may extend to a generation after the event.

Long-term effects of catastrophic crop losses are also indicated in a study of Manitoba's population trend (31) from 1871 to 1961. The greatest percentage increase occurred during the period 1871 to 1891, when immigration was flourishing. From that period, population growth slowed considerably, falling to about 15 percent from 1921 to 1931, 4.2 percent from 1931 to 1941, and increasing slightly to 6.4 percent from 1941 to 1951. The slow growth from the 1920's through the 1940's is thought to be due to many factors, including drought, grasshoppers, depression, war, abandonment of farms, and decreasing manpower requirements resulting from an increase in farm size and changes in technology (31). Manitoba's natural population increase, which takes into account birth and death rates, was lowest in 1936 and 1937 (31), again reflecting the economic and social disorders of the 1930's.

Although the impact of some insect outbreaks has been critical during Manitoba's history, the situation would have had even more disastrous effects had it not been for the research effort, and expense required to develop and apply control methods. The estimated annual savings of $50 million by developing varieties of wheat resistant to sawfly attack is testimony to the accomplishments of plant breeders. Biological control of insect pests has not been widely applied in Manitoba, mainly because potential target pests were generally considered as not being amenable to the classic method of control by the introduction of parasites, predators, or pathogens. A notable exception is the promising control of the larch sawfly, *Pristiphora erichsonii* (Htg.) (36), by parasite introduction. In the field of chemical control, one must give special credit to the pioneering work of Norman Criddle, whose accomplishments in the control of grasshoppers, white grubs, and other species have been well documented. The growing popularity of chemical control over the three decades following Criddle eventually led to the monitoring and regulation of sale of chlorinated hydrocarbons for agricultural use (aldrin, dieldrin, heptachlor, endrin, DDT, and lindane). Sale of these persistent insecticides declined rather steadily after Manitoba's Pesticide Control Act was proclaimed in 1963, and some of the materials were actually prohibited by 1968. Even in 1967, before constraints, the sale of chlorinated hydrocarbons in Manitoba was only 9,000 pounds[1] in terms of active ingredient. The cost of these persistent insecticides is infinitesimal compared with the $48 million spent in Canada on *all* pesticides in 1969. However, even moderate use of persistent insecticides can cause public concern over its contribution to problems of environmental pollution.

Public reaction to the use of persistent insecticides is a form of "pest impact" that is not new. It was present during the regime of arsenicals, but never to the degree demonstrated during the late 'sixties. There are growing conflicts on the wide use of insecticides on crops in agricultural and in recreational areas, and there is a danger that emotionalism of a new generation of activists will initiate premature legislation against certain insecticides that are useful if applied discriminately. These activists could play a useful role in society if scientists would cultivate their concern through better public relations. Scientists must measure and publicize the impact of pest outbreaks, the consequences of no control action, the benefits and disadvantages of chemical control of each target species, and the cost, benefits, and inadequacies of alternative control methods. More effort must be spent on alternatives that show little or no injurious side effects. Despite present problems of registration, we are rapidly developing the technology required for the effective use of pathogens in the control of some insect pests. We have not adequately explored the technique of inundative parasite or predator releases against pests of crops that are grown intensively. We are prone to accept the principle of other alternative control methods, such as use of sterile male releases, hormones, chemosterilants, attractants, and feeding deterrents, without fully appreciating the ecological consequences of their use. Until these consequences come to light we must continue to use chemical insecticides with reason and caution. In summary, unless we demonstrate and publicize the economic and ecological benefits of old and new control procedures, pest control is likely to lose ground before Manitoba celebrates her tricentennial anniversary.

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[1] Kolach, A.J. Man. Dept. Agr. Extension Service. Unpublished data.

REFERENCES

1. Abramson, J.A. 1968. Rural to urban adjustment. ARDA Research Report RE-4. Can. Dep. Forest. Rural Develop. Ottawa.
2. Anon. 1962. Wings over Manitoba - service meets varied needs. Can. Aviat. 35: 24-25.
3. Belski, P. 1966. History of mosquito control in greater Winnipeg from 1925 to 1966 and an outline of present operations. Proc. Entomol. Soc. Manitoba 22: 47-52.
4. Bird, R.D. 1961. Ecology of the aspen parkland of western Canada in relation to land use. Can. Dep. Agr., Winnipeg, Man. Queen's Printer, Ottawa.
5. Bird, R.D., W. Allen, and D.S. Smith. 1966. The responses of grasshoppers to ecological changes produced by agricultural development in southwestern Manitoba. Can. Entomol. 98: 1191-1205.
6. Bird, R.D. and W. Romanow. 1966. The effect of agricultural development on the grasshopper populations of the Red River Valley of Manitoba, Canada. Can. Entomol. 98: 487-507.
7. Brooks, A.R. 1958. Acridoidea of southern Alberta, Saskatchewan, and Manitoba (Orthoptera). Can. Entomol. Suppl. 2.
8. Ellis, J.H. and W.H. Shatev. 1943. Report of reconnaissance soil survey of south-central Manitoba. Man. Dep. Agr., Winnipeg.
9. Glazebrook, G.P. DeT(Editor). 1938. The Hargrave correspondence 1821-1843. Champlain Society, Toronto.
10. Gray, J.H. 1967. Men against the desert. Western Producer Prairie Book. Saskatoon, Canada.
11. Hildahl, V. and W.A. Reeks. 1960. Outbreaks of the forest tent caterpillar, *Malacosoma disstria* Hbn., and their effects on stands of trembling aspen in Manitoba and Saskatchewan. Can. Entomol. 92(3): 199-209.
12. Hind, H.Y. 1857. Essay on the insects and diseases injurious to the wheat crops. Lovett and Gibson. Toronto.
13. Hind, H.Y. 1860. Narrative of the Canadian Red River exploring expedition of 1857 and of the Assiniboine and Saskatchewan Rivers exploring expedition of 1858. Vols. I and II. Green, Longman, and Roberts, London.
14. Ives, W.G.H. and G.L. Warren. 1965. Sequential sampling for white grubs. Can. Entomol. 97: 596-604.
15. Jackson, F.W. 1941. Encephalitis epidemic, 1941. Question Mark 9: 4-9.
16. Jeness, Diamond. 1955. Indians of Canada. National Museum of Canada, Bull. 65, Ottawa, Canada.
17. MacKay, J.F., W. Stackiw, and R.A. Brust. 1968. Western encephalitis (W.E.) in Manitoba. Man. Med. Rev. 48: 56-57.
18. MacNeish, R.S. 1958. An introduction to the archeology of southeast Manitoba. Can. Dep. N. Affairs Nat. Resources, National Museum of Canada. Bull. 157.
19. Macoun, John. 1882. Manitoba and the great North-West. Thomas C. Jack, London.
20. Mair, W.W. 1969. Manitoba. *In* A. Bickerstaff (Ed.). Multiple use of forest land in Canada: A collection of summary statements provided by provincial and federal agencies. Can. Forest. Ser. Dep. Fish. Forest. Forest Management Inst. Information Rept. FMR-x-20. Ottawa.
21. Melvin, J.C.E. 1962. Insects attacking wild rice in Manitoba. Can. Dep. Forest. Bi-Month. Prog. Rep. 18: 2.
22. Mitchener, A.V. 1954. A history of grasshopper outbreaks and their control in Manitoba 1799-1953. 84th Ann. Rep. Entomol. Soc. Ontario, pp. 27-35.
23. Mitchener, A.V. 1955. A history of grasshopper control in Manitoba. Proc. Entomol. Soc. Manitoba, 11: 40-49.

24. Morton, W.L. 1957. Manitoba - a history. Univ. Toronto Press, Toronto.

25. Palliser, John. 1863. The journals, detailed reports and observations relative to the exploration of that part of British North America which in latitude lies between the British boundary line and the watershed of the northern or frozen ocean respectively, and, in longitude, between the western shore of Lake Superior and the Pacific Ocean during the years 1857, 1858, 1859, and 1860. G.E. Eyre and W. Spottiswoode. H.M. Stationery Office, London.

26. Prentice, R.M. 1955. The life history and some aspects of the ecology of the large aspen tortrix, *Choristoneura conflictana* (Wlkr.) (N. Comb.) (Lepidoptera: Tortricidae). Can. Entomol. 87: 461-473.

27. Pritchett, J.P. 1942. The Red River Valley 1811-1899, a regional study. Ryerson Press, Toronto.

28. Riegert, P.W. 1968. A history of grasshopper abundance surveys and forecasts of outbreaks in Saskatchewan. Mem. 52, Entomol. Soc. Can. 99 pp.

29. Romanow, W. 1955. The grasshopper survey in Manitoba. Proc. Entomol. Soc. Man. 11: 56-60.

30. Seamans, H.L. 1956. Field crop and vegetable insects. *In* Robert Glen (Compiler). Entomology in Canada up to 1956. Can. Entomol. 88: 322-331.

31. Sharp, E.F. and G.A. Kristjanson. 1966. The people of Manitoba. ARDA Research Report RE-2. Dep. Forest. Rural Develop. Ottawa.

32. Sinha, R.N. 1961. Insects and mites associated with hot spots in farm-stored grain. Can. Entomol. 93: 609-621.

33. Sinha, R.N., E.A. Liscombe, and H.A.H. Wallace. 1962. Infestation of mites, insects and microorganisms in a large wheat bulk after prolonged storage. Can. Entomol. 94: 542-555.

34. Taylor, F.R. 1956. Insect control recognized by special edition. Silver Sunshine 15: 1-3.

35. Thomas, L.H. 1958. The Hind and Dawson expedition 1857-58. The Beaver, Winter, pp. 39-45.

36. Turnock, W.J. and J.A. Muldrew. *Pristiphora erichsonii* (Hartig) (Hymenoptera: Tenthredinidae). *In* Biological control programmes against insects and weeds in Canada, 1959-1968. Tech. Commun., Commonwealth Inst. Biol. Contr. (In preparation).

37. Twinn, C.R. 1956. Insects affecting man and animals. *In* Robert Glen (Compiler). Entomology in Canada up to 1956. Can. Entomol. 88: 344-348.

38. United States Dept. Agr. 1965. Losses in agriculture. Agr. Res. Service Agr. Handbook No. 291, 122 pp.

39. Westdal, P.H. and C.F. Barrett. 1955. Insect pests of sunflowers in Manitoba. Can. Dep. Agr., Entomol. Div. Pub. 944.

40. Wood, H.E. 1955. The evolution in grasshopper control organization in Manitoba. Proc. Entomol. Soc. Man. 11: 50-55.

INSECTICIDES - PAST, PRESENT AND FUTURE

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Contribution to a symposium on "Insecticides - Past, Present and Future" at the 20th Annual Meeting of the Entomological Society of Canada and the 26th Meeting of the Entomological Society of Manitoba

INTRODUCTION

Twenty years ago the name DDT was a common household word. The communications media carried glowing reports of the tremendous increases in crop yields and vast advances which were being made in controlling insect vectors of diseases such as malaria as a result of the development of DDT and the other synthetic organic insecticides. Entomologists wrote glowing reports as to the advantages of these ultimate insecticides which would eliminate the various species of insect pests. The man who discovered the insecticidal activity of DDT was awarded a Nobel Prize. Today, 20 years later, DDT is still a household word. But no longer is it spoken of as a saviour of mankind. The communications media, fickle as they may seem, condemn DDT and its relatives both in news reports and in the editorial pages. The insect species which DDT and other organochlorine insecticides were to eliminate have instead become resistant, and survive in even greater numbers. In addition, because of their persistence and mobility, some of these compounds are causing serious environmental side effects, and biologists and conservationists, the public, and consequently the politicians, are up in arms over residues occurring in Coho salmon and the decline of the bald eagle and the peregrine falcon. There is strong pressure to restrict drastically, or even to ban, all pesticides and to rely completely on "biological control," and in a number of provinces, states, and countries partial bans on the use of persistent pesticides are already in effect. Knowledgeable scientists, however, concede that, with the majority of pest control problems, biological control is, at present, impractical if not impossible. More hopefully, it is now, or soon will be, possible in a number of instances to utilize chemical insecticides more sparingly by adopting techniques of integrated control involving the use of narrow spectrum chemicals combined with natural biological controls, or with commercially available biological control agents. However, even with integrated control the possibilities are limited. Consequently, for at least the next 10-20 years, chemical insecticides will continue to be the first line of defense in controlling insect pests. The development of new, less hazardous insecticides will not occur overnight, and it will be necessary to rely largely on materials now in use, but using techniques of application which will insure a minimum of environmental contamination. To accomplish this, we will certainly require more stringent regulations of pesticide use. And, if we are to develop narrow spectrum insecticides, whether they happen to be chemical or biological control agents, there is an immediate need for a vastly expanded research program involving a cooperative approach between Industry, Universities, and Government. We have with us today 3 outstanding speakers who will be discussing the Industry, University, and Government view of the insecticide problem.

In addition, we have a group present representing a fourth point of view. However, with the exception of a few vociferous, and perhaps misguided individuals such as myself, the membership of this group has remained largely inconspicuous and uncommitted in the pesticide controversy. I am, of course, referring to all of you in the audience - that is, the entomologists, and through you, your professional society. The pesticide controversy, at present, has become extremely polarized, with the pro-pesticide groups pitted against the anti-pesticide forces, and with absurd claims, charges, and counter-charges being made on both sides. It is high time that knowledgeable, impartial individuals stepped into the void which has been created and put forward some constructive suggestions to help solve the problems which do exist, and I feel that this is your responsibility, either as individuals or through the Entomological Society of Canada. The Entomological Society of Canada is particularly well-suited for this task because it does not represent just the pro-pesticide forces. In fact, it has a broad spectrum of membership encompassing not only economic entomologists, but physiologists, toxicologists, pathologists, systematists, ecologists, and also presents a cross-section of members drawn from Industry, Government, and Universities, and through amateur entomologists, the public. In fact, it represents a group of well-trained and concerned biologists who are probably more cognizant of the pros and cons of pesticide use and the possibilities for the future than many of the individuals who are presently dominating the public discussion on pesticide use. Surely, you as individuals and through the Society have a responsibility to put forward to the public, and to our Government realistic suggestions for solving the pesticide problem. You might argue that because of the wide diversity of interests and affiliations, it might not be possible to come up with an opinion on which the majority could agree, but I doubt if this is the case. For example, those of you who deal directly with insect control know that there is no way that we can do without chemical insecticides in the vast majority of cases. At the same time, many of you will admit privately that insecticides have been grossly misused, that you have serious reservations about the adequacy of the present procedures for registration of chemical insecticides at the Federal level, and the laxity of regulations controlling pesticide use in most of the Provinces, and that you are seriously concerned about the failure of the Canadian Universities to train specialists in economic entomology to help solve the problem. On the other hand entomologists concerned with the development of biological control agents will generally admit to the limitations of these techniques, but at the same time protest bitterly over the limited research support for this approach and the severity of the requirements for registration of biological control agents. Finally entomologists are basically biologists and naturalists at heart and are as concerned about environmental side effects as anyone. Consequently, I feel that up to the present, you have been neglecting your responsibilities by not contributing either individually or through the Society, realistic suggestions to the solution of the problem. The problems relating to the use of pesticides will not be solved by emotional charges and counter charges or hysterical headlines in the press, but by sound scientific assessment of the problem by Societies such as this. I hope that the 3 papers to be presented today will provide a basis from which reasonable discussions on the pesticide problems can begin.

INSECTICIDES - PAST, PRESENT AND FUTURE

A UNIVERSITY VIEWPOINT

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ABSTRACT

As intermediates between the developers and producers of insecticides (industry) and the arbiter of their permitted regulated application (government), university research units should develop independent and supplemental detailed information to help guide both initial and periodically revised decisions on usefulness and on safety-in-use. Typical university research interests in this area should include extensive and continuing evaluations of field performance and merit, establishment of realistic fates and persistences of all residues introduced into the total environment involved, long-term studies of pronounced effects of these residues on any organism that would normally be in or near the target area, and the continuing scrutiny, development, and exploitation of analytical methodology adequate to these tasks. Whether universities can efficiently search for new insecticidal compounds is a moot point, although mode-of-action evaluations are almost exclusively university activities and can conceivably point the way to new candidate insecticides.

Traditionally, university agricultural laboratories have been largely regarded as unbiased testing centers, as critics, and as training centers for research workers. Being largely responsible for the orderly development and recommended adoption of practical and practicable advances in agricultural production in their geographical areas and interests, they must remain impartial for maximum effectiveness in assisting both industry and government. Past and present history in the field of insect control abundantly demonstrates that universities have played major roles in establishing the present insecticide armamentarium; it is to be hoped that these contributions will be expanded despite the recent tendency for industry to depend less and less upon universities for developmental work with candidate materials. Industry, government, and universities must cooperate fully again in the present popular denunciation of all pesticide chemicals and the now unrealistic costs of developing a new material under today's grossly expanded social and technical requirements or chemical pest control will not survive.

It is indeed a welcome opportunity to express some of my personal interpretations of a university's viewpoints, adopted responsibilities, and assumptions of certain restrictive obligations in the development and ordered evolution of pesticide chemicals for legalized use in modern agricultural production. These interpretations would also apply to certain aspects of the maintenance of the public health through adequate pest control. Although insecticides have pioneered the path from the use, by our remote ancestors, of smoke to control annoying flying pests to the present-day arsenal of effective yet regrettably controversial pest-control chemicals, most of the remarks in this entire symposium will apply to all pesticide chemicals. As pest-control chemicals have evolved during the past 75 years, intervention by government and contributory involvement by land-grant university and college research personnel increased dramatically, but university research is now being channeled from applied contributions in this area.

Initially, both state and federal governments were largely concerned with consumer protection against harmful deposits of about 10 insecticides, excluding fumigants, on treated foodstuffs. This concern has mushroomed to include safety-in-use in its manifold aspects plus the imposition of requirements for usefulness and rigid scrutiny for minimum undesirable environmental effects. At the same time university and college involvements have also changed. In contrast with traditional European universities, founded to provide religious then classical educations, American land-grant universities and colleges[1] were established in every state to serve the agricultural interests of each state through research, the dissemination of practicable information, instruction, and training in the vanguard of agricultural knowledge. Initially, then, in the insecticide field their interests consisted almost exclusively of evaluating field performance in terms of:

1. The design and improvement of formulations.
2. The various application techniques available and the development of new ones.
3. The usually random biological testing of every conceivable toxic or otherwise insecticidal chemical.
4. The correlation of magnitudes and stabilities of spray and dust deposits with insect-control performance, with dosage, and with weathering factors.
5. The practicable removal of vestigial deposits from the crops at harvest time.
6. The chemistry of the available insecticidal materials and formulations.

In the United States, these interests resulted in many important contributions, usually worked out in close cooperation with the equipment manufacturers, with the gestating agricultural chemicals industry, and with the U.S. Department of Agriculture. "Government" contributions along these lines during this early period were almost exclusively from a few state Departments of Agriculture and the U.S. Department of Agriculture (U.S.D.A.); the U.S. Food and Drug Administration (FDA) at that time was concerned with possibly harmful amounts of these chemicals residual on produce shipped interstate, with scanty toxicological and pharmacological attention to these early insecticides, and with no requirements about insecticides in meat or milk.

The equipment manufacturers worked then — and still do — very closely with both university and U.S.D.A. personnel in the design and improvement of application equipment, although university involvement in this area today is largely through the new breed of agricultural engineers and the extension entomologist rather than exlusively through the field or "economic" entomologist.

Similarly, the agricultural chemicals industry has always cooperated closely with both university and government in the development of successful, needed, and economically acceptable insect-control chemicals and other agents. Initially, this industry relied almost entirely upon the U.S.D.A. and the universities for suggestions for candidate insecticides, for the composition of formulations of both new and established products to meet local requirements and conditions, and for all field evaluations of acceptability and performance, including correlations of efficacy with deposits. Direction as to the limitations of practicality of formulations and of field tests needed to complete a spectrum-of-activity survey or to establish performance under a variety of geographical and meteorological conditions was provided by the industry. At this time there were perhaps a dozen insecticide

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1) Hereafter the term "university" will mean both universities and former and present colleges in the United States; most stage colleges are now designated "state universities."

chemicals and a like number of companies engaged in the manufacture of the parent chemicals. When a promising lead for a new product or an improved formulation was developed by a university, industry would often loan personnel to the university to help develop the idea or chemical to commercial maturity; out of this type of cooperation evolved the industrial grant-in-aid support as a substitute for loaned personnel.

Thus, it is recognized that until about 1940 government [in the narrow sense of only the six U.S.D.A. field stations including Beltsville (17)], about 12 major suppliers, and about 12 of the land-grant universities worked hand-in-hand upon all problems associated with effective, economical pest control. All segments of this triumvirate mutually benefited from new developments in the art of formulation, in techniques of application, and in any other developments that would advance the art and science of pest control.

In rapid sequence there then came the recognition (by a university) that organic insecticides penetrate into plant parts, the discovery (by industry) of systemically acting organic insecticides, and the recognition (by government and university) that most of these post-1940 insecticides will persist into food and animal products and may persist — and thus could have damaging effects — in almost all segments of the environment. As one consequence, this three-way picture of mutually buttressing, free-wheeling, and free-handed cooperation in all aspects of commercial pest control has changed.

With these developments are now associated about 50 major insecticides and acaricides of greatly diverse types and directed intervention by government in the broadest sense. This intervention has taken the form of the tolerance concept and its many subsequent implications and ramifications, the possible and probable direct effects upon man from the legalized use of these chemicals, and the probable violation of at least the local environment from any use. Thus federal governmental bodies now directly concerned with legally sanctioned insect control measures include the U.S. Department of Agriculture (U.S.D.A.), several agencies in the U.S. Department of the Interior (U.S.D.I.), and the U.S. Department of Health, Education, and Welfare (HEW) through both the Food and Drug Administration (FDA) and the Public Health Service (PHS). Just a few years ago the only federal requirements for new insecticides and formulations involved proofs of usefulness and of efficacy and of the quantitative evaluation of persisting deposits at harvest (at the roadside) and sometimes after washing. Present-day requirements and requests to justify their use in commercial agriculture now include information on:

Nature and composition of product (including all formulations).

Usefulness against specified pest insects on specified crops or animals when applied in specified ways.

Efficacy under the above circumstances and in several geographical areas.

Natures and locales of persisting residues, including major toxic metabolites or other *in-situ* alteration products in the harvested foodstuff and in the soil and in run-off water from the treated area; possible transfer to other crops grown subsequently in the area must be considered. Possibilities for residue reduction or destruction should be considered.

Residue analytical methodology adequate for the above objectives.

Acute and chronic oral, dermal, and inhalation toxicities of the major toxic species in each product.

As detailed and as convincing-as-possible information for each insecticidal chemical on carcinogenicity, reproduction (including teratogenicity and mutagenicity), potentiation, and probable nutritive involvements including enzyme induction and storage displacement.

Reasonably long-term effects upon several species of wildlife including fish, birds, and usually small animals; some marine organisms may be included if they may reasonably be involved. Possible food-chain build-up must be evaluated.

Major, persisting photosynthetic products may require characterization and evaluation as to toxicity and amounts present from field use.

The evolution of this succession of federal requirements and requests for purposes of obtaining license to sell, of registration, and of tolerance classification has resulted in the gradual imposed categorization of areas where university responsibilities are properly involved in securing parts of this information, as contrasted with the free-wheeling university involvements in earlier times.

Thus, for reasons of maximum economy, promptness, and direction in satisfying these very expensive requirements, the agricultural chemicals industry now characteristically coordinates and accumulates through its own entomologists most of the final usefulness and efficacy data from the U.S.D.A. and universities but often provides some of its own for major crops. It usually no longer depends upon the U.S.D.A. and universities for information upon natures of residues and their decay, for analytical methodology, for persistence of residues in soil and water, and for wildlife studies (prompted by the U.S.D.I.); it may depend upon them for characterizations of photosynthetic products. Rarely does industry rely upon universities, the U.S.D.A., FDA, or the U.S.D.I. for the mammalian toxicological and pharmacological requirements. Several of the giants in the industry do this work themselves, whereas others contract it to private institutes and laboratories. Since fulfilling this list of U.S. requirements and objectives will cost from 4 to 8 million dollars and requires many years for each chemical, it should be pointed out that around the world only the giants are still in the insecticide chemical business, and this roster is undergoing attrition.

Presumably because of the lack of research challenge, universities have been reluctant to become involved in non-human toxicology and pharmacology of the sorts required above, although industry has indicated (13) this type of long-term research should be delegated to universities. Because of the obvious research challenge, however, universities have become deeply involved in mode-of-action and metabolic and other "total fate" studies with both old and new insect-control chemicals and with their photoproducts, and with the associated analytical methodology.

As a further change from the old pattern, application techniques and equipment are now standardized only in local areas, and the compositions of formulations are closely guarded trade secrets. Also, in the early stages of the development of an insecticide, the university or U.S.D.A. field entomologist now usually works with the new chemical under code number and has no knowledge of its structure until patent clearance is obtained by the company.

With their own elaborate facilities and full complements of entomologists, other biologists, chemists, biochemists, toxicologists, pharmacologists, and statisticians, most surviving members of the agricultural chemicals industry have tended to become self-sufficient in all the above matters during the past 20 years; most of them even have their own experimental farms, often in several locations around the world.

This pattern of interests and responsibilities has emerged because these increasing difficulties of registration may make critical any delays in gathering the required information; clearly, industry can usually accomplish such tasks more quickly if it retains direct control of the personnel involved (10).

This situation was undoubtedly implemented by the increasing reluctance of university personnel to undertake guided practical research which must be kept on schedule, unidirectional, and stopped at a fixed objective. On the other side, university research leaders have steadily become more and more involved with teaching, with graduate students, and with continually decreasing technician support so that most of their research efforts must now be of acceptable academic thesis quality. Despite these increasing trends there is fortunately still strong feeling at all levels that universities continue to remain independent, impartial sources of needed information, either as primary or as confirmatory supplier in those areas above where competency has been demonstrated. Even though industry may have partially supported a desired program, a university cannot afford publicly to show bias in any research endeavor. University research must attempt to remain unbiased, for governmental research may be politically motivated or understandably over-protective and industrial research is necessarily economically motivated.

The future role the university should play in the evolution and development of insecticides is not clear. It is clear, however, that government is going to be more and more deeply involved both formally and informally with environmental protection, and that pesticide chemicals can represent a major contribution to environmental deterioration. In addition to foods and feeds, the evaluations of the significance of these foreign chemicals in air, water, and soil, and their transfer to unwitting, non-target plant and animal life will be required for every material. Efforts to develop more biodegradable pesticides obviously will be stimulated, yet there will always occur situations where some persistent chemicals will be required for emergency use or where persistence is essential (e.g., termite control under buildings); also, persistence is often a major economic advantage for the farmer. For some time the presently available, persistent organochlorine insecticides will remain ideally suited for certain public health applications because of their low acute mammalian toxicities—and thus minimum hazard to the applicator and to the occupants of treated areas—and their low-cost, long-term effectiveness.

The traditional roles, in this area, of land-grant institutions have been to conduct research, to produce scientists, to train technicians, and sometimes to serve as impartial sources of new or evaluative information or to provide referee-type data to support (or weaken) a contention either of government or of the agricultural chemicals industry; qualified university personnel in well-equipped laboratories should be competent independent critics (12).

The research has been both theoretical and applied, but the latter type is currently being deemphasized because of the difficulty of securing funds and positions for technicians, the very strong emphasis on funding for graduate students, and the awkwardness of designing an academically acceptable thesis problem around much applied research, as pointed out earlier. Consequently, graduate-school training in this area for some time has emphasized mode-of-action studies, non-quantitative metabolic fate studies with plants, small animals including insects, and soils, and the resultant inevitable urge to synthesize new pesticide chemicals as these mechanisms are clarified for particular compounds. The result has been the rapid evolution of very narrow specialists in universities, such as insect nerve physiologist, insect behaviorist, enzyme toxicologist, mode-of-action toxicologist, insecticide photochemist, and others. The information accumulated by these specialists will eventually lead to new types of pest-control chemicals, of course. Another generously funded area of graduate training is that of the so-called environmental sciences, but here again the problem of an academically acceptable thesis problem occurs, often to the exclusion of urgent applied-research needs.

This trend has been offset somewhat by marked increases in the numbers of post-doctoral fellows and non-Ph.D. research trainees working in this area, usually supported by industrial grants. These people often work upon applied problems of mutual interest to the university and to the sponsor.

The production of scientists by universities is mandatory, for there is no other source of supply for either government or industry.

The providing of evaluation services by the university has occurred in numerous ways. For example, governmental agencies often require residue information from several areas; the industry may provide the basic detailed information required then the industry or the state will ask universities to spot-check the findings in their own geographical areas.

Similarly, a university with particular talents or with particular facilities will be asked by industry to use these assets to solve a particular short-term problem. Rarely has industry financially supported a long-term pesticide research problem; with few exceptions this type of support has come from federal grants, with the grant application necessarily tailored to appeal to the granting agency.

Because of these trends plus the advantages of direct control over personnel, the agricultural chemicals industry is doing more and more of its own product development, which now includes field testing, development of residue analytical methods, metabolite studies, compatibility studies, evaluations of effects on fish, marine organisms, and wildlife, residue persistence evaluations in foodstuffs, water, and soils, and environmental migration and food-chain build-up studies. At one time these areas were largely the province of the university, as stated earlier.

What should be the function of the university in the area of pesticide chemicals and perhaps in agriculture in general? University policies should build agriculture. The following interconnected, detailed points *in toto* comprise an elaboration which represents a summation of ideas from some university, government, and industry representatives in the pesticides field.

1. The basic purpose of any university should be to seek the truth, apply these truths wherever and whenever applicable, and disseminate both the truths and the result of their application through the education of both students and society in general (8). The present controversy over the value of pesticide chemicals vs. environmental integrity stems in large part from the failure of knowledgeable university personnel to make themselves heard by the general public. Universities should both provide and coordinate information (3), then distribute it effectively. The university should be the "meeting ground" for all parties, for free-wheeling exchanges of ideas and relevant data; with the university personnel governmental representatives should not feel they are speaking officially, and members of industry should expect their trade secrets will be respected.

2. As with industry, and to a large extent government, the land-grant universities are too heavily dependent upon sources of funding for the direction the research programs take (6). A research team, with internally and highly trained personnel, often can be kept intact and functioning only because funds for a certain—but not necessarily desired—activity are achievable. Complete "freedom of research" is now lip service. To supplement the economic motivation of industry and the conservative, necessarily over-protective motivation of government, the university researcher should work largely with public funds and develop basic principles and broad generalities of public value (1, 3, 11) yet withal maintain a continuing program to achieve practical goals that will satisfy his obligation to the agriculture of his state and to his community (6). Industry often develops partial basic information but cannot pursue it because of the economic return factor; this information should be made available to interested university staff to pursue in any direction desired (10). What constitutes good agricultural practice is the purview of the university system so long as the university remains problem oriented rather than product oriented (5, 8).

3. As training centers, universities should make more of an effort to expose students to the types of problems faced daily by both industry and government (3). Highly specialized graduates must often be trained by the employer in the practical matters so vital to him. The academician can learn of these practical problems by visiting industries and governmental agencies, from some literature (e.g., ref. 15), and by consulting (as a form of teaching) with industry or with government; the industry in particular has been lax in attempting to keep the universities up to date in these matters so that the information could be passed along to students (3). Regular contacts with both industry and government are needed by the student during his entire graduate program. In this connection, there should be broader recognition by universities that many practical or applied research problems can be acceptable thesis investigations.

4. Because of their generally accepted reputation for impartiality and objectivity, universities should make every effort to remain free of bias. There are many instances where university personnel are considered the only unbiased experts, as in numerous governmental and international (e.g., WHO) committees and advisory bodies (4, 5, 10, 14). Also, industry develops and collates a tremendous amount of data to attempt to demonstrate safety before tolerances are assigned, as discussed earlier; however, there are never enough data to assure full safety to all aspects of man and the environment, and there must be continual review of possible hazards. The university could play an exceedingly important role in serving as a scientific critic, advisor, and observer to watch for and call attention to impending difficulties, especially if done in a spirit of teamwork (2, 5). Unfortunately, even in a university the extent of bias depends upon the research attitude (objectivity) and integrity of the individual concerned (1, 6). When a situation calling for unbiased data appears to contain probable litigation, however, universities are prone to avoid becoming involved (12, 16) except as expert witnesses. An honest search for truth should preclude bias (8).

5. As more is learned about the natures and behaviors of pesticide and other industrial chemicals, there is need to make more comprehensive testing of their possible effects on the environment before the chemicals are disseminated around the world. Coordinated and directed research effort will be required to achieve this goal (2, 5, 6). This effort clearly must be both "ivory tower" and "applied" to help establish safety-in-use criteria (2, 5) for all these chemicals. Thus, the Mrak commission (15) reported a very large number of unsolved practical problems despite the enormous amounts of money and work spent on our present pest-control chemicals. Those individuals planning the work clearly have not fully recognized some very practical safety problems (2, 5), especially in terms of long-term consequences of widespread use (1).

6. University research units should eliminate from further consideration for particular problems and areas those chemicals and practices which are not adequately effective and/or economically feasible. Effective and economically acceptable chemicals should be developed to the point of grower use (1). There are other examples of this sort, where neither government nor industry has a direct responsibility or obligation, and where the grower does not have either capabilities or facilities, such as the fates of residues and their ecological influences (6, 12).

Aside from students, the primary responsibility of the university is to the public, rather than to a favored few, although for a particular problem it may be most expedient for a university to work with a governmental agency, an industry, or a grower group so long as the test of public interest applies (8).

7. Too often the university seems to have acted as a spring-board for industry for prematurely launching new pesticide chemicals (4).

8. The patent policies of universities should be unified (1, 9, 10, 11). University personnel have produced new pesticide chemicals, yet often the patent situation is such that an interested industry would have no protection in developing and marketing the chemical (9, 10, 14).

9. University research should be funded adequately by public funds (6, 11). Dependence upon grants, contracts, and fellowships is as limiting to the scope of a university as it is to a private laboratory or institute, as discussed earlier. Grants should always be acceptable for supplemental studies, however (6).

The new Environmental Protection Agency may be expected to be a major contributor to university research in some of the research areas discussed, however (5).

10. Universities should not do routine testing (7, 10, 14, 16). The university should have no role once a procedure becomes routine and the objective is to turn out large amounts of data (6), except, for example, where state requirements are that the state

university shall secure representative residue data for each insecticide in each use in that state, or where expertise and equipment exist for establishing performance standards (5). The testing of goods or services within a university often implies endorsement or even selective involvement with individual companies (8).

11. University personnel should be encouraged to consult with industry and government (5, 6, 7, 9, 10, 11, 16) so long as there is no conflict of interest (4, 8). Consulting can bring a researcher up to date for more effective teaching (3), for breadth of research interests (16), and for maturity in a given field.

12. University research programs should be responsive, also, to the needs of commodity groups not able to undertake extensive investigations which will ultimately benefit both the grower and the consumer (1). Similarly, there are certain functions a university can perform more efficiently than can a governmental agency; the latter should solicit help not only for advice but also for data if university expertise or facilities will save either time or money.

13. There has developed a gap in understanding between academic and commercial interests; too much of the burden of testing and recommending a product has fallen on industry's shoulders (12, 13). It might be time to shift some of this level of responsibility back where it belongs—to the tax-supported agencies (12, 13). Industry should rely upon tax-supported corroborators at the state and federal levels for specific guidelines or recommendations as to how, when, where, and what insecticides should be applied or not for man's best advantage (12), based on ample data.

In summation, it is clear that the escalating problems associated with foreign chemicals in foodstuffs and in the total environment cannot be solved satisfactorily without even closer cooperation among industry, government, universities, and the consuming public (11). The expertise, facilities, and capabilities of each must be exploited to the fullest if we are to maintain even our present living standards and conditions. Patience, temperance, and foresight will be required on the part of each to achieve an entirely satisfactory "risk-vs.-benefit" equilibrium involving essential foreign chemicals in our modern civilization.

Universities must return to a major role in the orderly development of new pesticide chemicals and in the gathering of information on their safe and effective use in terms of the total environment; the final disposition of pesticide chemicals in the biosphere is most assuredly a university responsibility. With the present hysteria about the decay of the environment, and the resulting frantic involvement in pest control of so many disciplines from ecologist to social scientist to systems analyst, who will set tomorrow's standards for insect control chemicals? Will it be the ichthyologist, the ornithologist, the ecologist, the eutrophication expert, the systems analyst, the political scientist, the social scientist, the residue and metabolism chemist, the toxicologist, or will it be the entomologist? It probably will not be the entomologist, for with all these forces—plus the very significant pressure to work in areas where funds are available—working against him and his entomologically useful chemicals, it will clearly be a matter of serendipity to bring a good insect-control chemical to maturity.

REFERENCES

(1) G.E. Carman. Personal communication of 1 July 1970.
(2) J.W. Cook. Personal communication of 20 July 1970.
(3) D.G. Crosby. Personal communication of 14 July 1970.
(4) S. Dormal-van den Bruel. Personal communication of 20 July 1970.
(5) T.H. Harris. Personal communications of 31 July and 25 August 1970.
(6) L.W. Hazleton. Personal communication of 8 July 1970.
(7) M. Johnson. Personal communication of 20 July 1970.
(8) J.B. Kendrick, Jr. Personal communication of 15 July 1970.
(9) G.K. Kohn. Personal communication of 13 July 1970.
(10) D. MacDougall. Personal communications of 27 July and 18 September 1970.
(11) A.G. Salter. Personal communications of 21 July and 27 August 1970.
(12) M.J. Sloan. Shell Chemical Agricultural News *17* (4), 1 (1970) and personal communication of 19 August 1970.
(13) I. Smith. Statement of 6 November 1970, Berkeley, Calif.
(14) H. Tietz. Personal communication of 22 July 1970.
(15) U.S. Department of Health, Education and Welfare "Report of the Secretarys' Commission on Pesticides and their Relationship to Environmental Health." Parts I and II Washington, D.C. December 1969.
(16) G.W. Ware. Personal communication of 8 July 1970.
(17) W.E. Westlake. Personal communication of 30 July 1970.

INSECTICIDES - PAST, PRESENT AND FUTURE

THE GOVERNMENT VIEWPOINT

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Contribution to a symposium on "Insecticides - Past, Present and Future" at the 20th Annual Meeting of the Entomological Society of Canada and the 26th Meeting of the Entomological Society of Manitoba

When I was invited to participate in this symposium I was perhaps naive in accepting, since only your elected representatives can make policy and provide an overview of the "Government Viewpoint". In searching for a text for this lecture I did find one from an authoritative source, the Prime Minister. *

"In a matter as familiar and as obvious as water pollution, we are now paying for the decisions taken or avoided ten years ago. At the end of the seventies we will be living with the results of decisions taken at the beginning of the decade. Planning, whether it is by a political party or a government or a private company, must operate in a scale of time which is sufficient to permit it to alter the future. We should now be thinking not only of the type of goals we wish to achieve in our society, but of their relative importance, and of the best means of achieving them within a reasonable time."

This is the basic philosophy which should be developed in approaching the decision-making process for management of pest control and pesticides in the next decade.

Our total modern Canadian experience in the process of developing policies and programs to manage insecticides is relatively brief. It can be spanned by the average professional career of Canadian entomologists, from lime-sulfur to carbofuran as chemical tools, from lead arsenate residues in tobacco threatening loss of markets for the crop in the 1930's to the phenomenon of occurrence of DDT metabolites (DDE, DDD) in the food chain of peregrine falcons being partially involved in failure of hatching success of these and similar predatory birds (1960's).

Planning of management through the political process of establishing goals and objectives at both federal and provincial levels is a continuing process of evolution. The criteria for management of insecticides of only 10 years ago are not good enough for tomorrow. Hopefully the process of policy and program evolution in both research and regulatory fields will be pliable enough to adapt to new scientific information and changes in economic and social values as they become available, without precipitous actions forced on politicians by the vocal theatrics of the would-be experts on everything.

F.W. Buser, Chief, Management Services, Canada Department of Agriculture, has been carrying out a study of "pesticides management and organization". Part of his views and recommendations were presented recently to a Symposium on Management of Pesticides,

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* "Technology: Ignorance and Alienation or Knowledge and Control", Rt. Hon. Pierre Elliott Trudeau — An Extract from the Prime Minister's remarks at the Liberal Party Conference, Harrison Hot Springs, B.C., November 21, 1969.

held in July 1970 in Ottawa by the Agricultural Pesticides Society at the 1970 meetings of the Agricultural Institute of Canada. In examining the Environmental and Resources Management system in which pesticide policies and management practices should be developed the emphasis on new expanded thinking is readily apparent. (Appendix A)

In this scheme, "Man is at the centre. His needs relate to Food, Natural Resources, Health, Wildlife and Aquatic Life — his environment of total nature. The expression of his needs is also dependent on, and influenced by, the level of available knowledge and his access to information. Knowledge and capability of making information available is a resource like food and health."

"The management decisions on man's needs are influenced by such factors as: economy, quality, satisfaction, well-being, effectiveness and possible risks. In other words, decision-making is influenced by objective and subjective factors. We have lately discovered that the subjective factors might be more significant than the objective criteria. It is also a truism that man's need for quality becomes more pronounced once he has satisfied his elementary needs."

". . .the needs of man are affected by a set of values and behaviour of society, which in turn are influenced by science, technology, civilization, economy and legislation" the sum total of these is expressed by his culture.

In fitting pesticide management into this scheme a balance between management of resources and management of the environment has to be found. The question which can only be settled by the political process is "*What are the results we wish to achieve?*" Then a total system of management of pesticides will have to be developed to answer the question of "how to establish and maintain the balance". (Buser, 1970)

The Present Situation

The Prime Minister of Canada in making a statement on DDT in the House of Commons in November 1969 provided the general objectives of the present government — "an important objective of my government is the protection and enhancement of man's environment, and in harmony with this objective, the protection of man, crops and livestock from pests." The important decisions yet to be made by government are those associated with defining the desired level of environmental quality and how these will be harmonized with an expanding economy. Since pesticide management and resources management are both firmly based on scientific research, the only way desired results will be achieved will be "in close association between research (scientific, economic and social) regulation, and education."

In the USA, Dr. E.M. Mrak, the Chairman of the U.S. Department of Health, Education and Welfare Commission on "Pesticides and their Relationships to Environmental Health", proposed the following management philosophy and action program:

1) "Chemicals, including pesticides used to increase food production are of such importance in modern life that we must learn to live with them;
2) "In looking at their relative merits and hazards we must make individual judgments on the value of each chemical, including the alternatives presented by the non-use of these chemicals. We must continue to accumulate scientific data about the effects of these chemicals on the total ecology; and
3) "The final decision regarding the usage of these chemicals must be made by those government agencies with statutory responsibilities for the public health, and for pesticide registration."

But, I would add a rider to these. Regulations must be based on having information first to ensure they will work.

Looking Backward

In the first phases of insecticide use the primary concerns were the protection of the user from occupational hazard, that innocent third parties were not injured and the purchaser was protected against fraud in the packaging and sale of the merchandise. Efficacy of the insecticide was the prime concern of entomologists. Legislation and research were geared to these objectives.

With the introduction of the first generation of organic insecticides, programs and policies evolved to cope with one new parameter in the form of residues in food of man and domestic animals. In entomological research, the gross undesirable side effects of DDT in precipitating population explosions in mites quickly drew attention to the non-selective features of this generation of insecticides and set the stage for a more intensive quantitative study of the role of natural factors in regulating insect populations. Hopefully, this would also lead to recommendations for the use of narrower spectrum insecticides, better timing of applications to achieve maximum effect with minimum amounts of insecticide, and minimal undesirable side-effects on biotic agents contributing to natural control. There was realization that it was necessary to develop a capability to predict the behaviour and persistence of residues. In support of these objectives, insecticide chemistry and research on mode of action of insecticides saw their initial expansion from almost a non-existent program into one which is gaining international recognition for its quality.

At this stage legislative policies and regulatory programs shifted to fit the situation. The philosophy underlying the administration of the Food and Drugs Act as it applied to pesticides adapted to the current situation and procedures for the registration of pesticides under the Pest Control Products Act were made reciprocal with those for regulating residue limits in food. As supplementary actions new regulations concerning pesticides were also added to the Fertilizers Act and the Feeds Act. New parameters for establishing criteria for acceptability of residues in food have been developed in the past ten years and it is recognized by those concerned that the process must continue to adapt to new scientific knowledge and erect new criteria as the supporting work in chemistry, toxicology, pharmacology and epidemiology of insecticides expands. In some provinces legislation affecting pesticide use and sale was introduced and provincial residue laboratories were developed.

We now have in Canada 17 federal and 102 provincial acts which in one way or another bear on the regulation and use of pesticides.

At the federal level, five departments are primarily concerned:

1. Agriculture
2. Health and Welfare (Food and Drug and Occupational Health)
3. Fisheries and Forestry
4. Indian Affairs and Northern Development (Wildlife)
5. Energy, Mines and Resources (Water)

Also, Industry, Trade and Commerce is concerned with trade aspects and the Department of External Affairs deals with international aspects.

The overall current federal relationship is summarized in Appendix B (Buser, 1970). Five of the departments concerned have research programs and facilities related to pesticides and all in one way or another have some but varying capabilities for laboratory work to support their regulatory or control programs.

Buser has several critical comments on coordination. The main tools at the federal level for this purpose are the Federal Interdepartmental Committee on Pesticides and the Interdepartmental Committee on Forest Spraying. Both have an advisory function but no authority, but "since the representatives are senior public servants, their opinions carry considerable weight", but "an effective coordinating public service body on a national and provincial level is missing."

However, all is not negative. In the 1960-70 period there was produced through the political process a reorganization of national, regional and provincial advisory committees concerned with *recommendations for pesticide* use. Through recruiting and training the development of a nucleus of regional scientific, regulatory and extension specialists has made it possible for most decisions concerning insecticide use to be made on a local basis, based on the critical evaluation of scientific data as it pertains to local situations. Regional workshops are improving the calibre of pesticide chemistry in support of these programs.

A great deal of this has been done through the reviews and recommendations made by the Canada Committee on Pesticide Use in Agriculture to the Canadian Agricultural Services Coordinating Committee. The most recent operation of CCPUA has been the development of a check sample analysis program for pesticide residues involving over 30 laboratories and the sponsorship of the eastern Canadian workshop on residue chemistry methods.

In this decade (from 1960-70) it was necessary to develop a capability for participation in international scientific critical reviews, political discussions and negotiations in the United Nations and other agencies concerned with attempting to establish international agreements on pesticide residues which may remain in food moving in international commerce and methods of detecting and measuring them. The spin-off from these international programs of review is assisting in our own internal review of the status of the pesticides concerned.

The 1970's

In the 1970's we are into a new situation. Pesticide management policies, regulatory and research programs are now in the process of being tightly bound up in policies being developed for pollution control. Criteria for desirable environmental quality for man are in an advanced state of development as compared with other sectors and inhabitants of the environment. The second generation of modern insecticides will have to be carefully examined from the standpoint of air, water and soil pollution, possibly particularly from the standpoint of their propensity for getting into food chains on non-target essential organisms. We can only do part of this, since the task is so overwhelming. We will need advice from other scientists as to priorities.

Governments have the responsibility to ensure that as long as they are needed, insecticides will be introduced and properly used for the economic production of food and fibre, the maintenance of public health through the control of disease carrying insects and providing comfortable situations for the enjoyment of our increasing leisure time. Balanced against this is the necessity for developing policies and programs aimed at the maintenance of a politically selected level of environmental quality. At this stage in time those agencies responsible for the welfare of fish, wildlife, water, air or soil quality are not yet in a position to recommend limits of acceptability for the second generation of pesticides or their metabolites and degradation products in those sectors of the environment for which they have been made responsible by the political process.

You may be aware that in June 1970 the decision was taken to establish the National Research Council Associate Committee on Scientific Standards for Environmental Quality. This new Committee will, no doubt, address itself to these gaps. It will have a full-time working Secretariat, and will develop a national information service on the scientific and technical aspects of pollution standards.

Currently in Canada there is under discussion at senior government and political levels the possibilities of establishing an "Environmental Council". The 1969-70 Annual Report of the Science Council of Canada (p. 36) reports that "The Science Council is actively pursuing the problem and plans to make a more detailed proposal in the near future; however, it may well be that the government itself will take the initiative in proposing some such organization." The Resources Ministers Council of Canada, as a result of continuing work since the 1966 CCRM Pollution Conference, has made a series of recommendations to the Premiers Conference which convened in Winnipeg earlier this month. That conference recommended that additional resources be provided to the Canadian Council of Resource Ministers in order to allow it to function as an environmental council in an advisory capacity.

Buser (1970) has also related the solution of the pesticide management problem to a possible "National Environmental and Resources Management Commission" (Appendix C).

Part of the current dissatisfaction is a feeling that there is always the danger that government regulatory agencies charged with the administration of various acts can become too far removed from the scientific advances. They can also become captives of the industry or resource they are supposed to regulate or service. The regulations themselves can become a reason for policies and programs becoming obsolete unless there is a continuing reevaluation of the regulations and procedures used to make them work.

From all the published statements available and discussions I have been involved in suggest to me that any new environmental body that may be established in Canada will *not* be along the lines of that now being developed in the U.S. Instead the resource based agencies at both federal and provincial levels will probably still have responsibility for their individual research, regulatory, information and education programs, *but* policy interpretation, policy advice, program review and program assessment will probably become the responsibility of a new body.

At this point I should now leave the abstract business of the political processes and management decisions and turn to a few matters of probably more immediate concern to Canadian entomologists.

1970 Reviews of Selected Insecticides - Pilot Program

DDT –

use patterns were revised in November 1969, 12 crop uses remain as opposed to 62 previously.

Current use patterns were sent to CDA research entomologists and provincial governments in the fall of 1969 for the organochlorine insecticides and *parathion.* Their comments were solicited on:

(a) specific requirements to retain particular uses of these compounds,
(b) adequacy of information pertaining to uses to be retained,
(c) availability of suitable practical replacement compounds,
(d) probable replacement compounds for those uses to be dropped and adequacy of information on them.

These comments were collated and formed the basis for a work planning meeting held in Ottawa on April 27-29, 1970. CDA research and regulatory staff immediately concerned and Dr. A.S. West and Professor F.L. McEwen participated. Food and Drug representatives also briefed the meeting on the status of toxicological data pertaining to residues of these insecticides in the diet of man.

TDE –

no need to retain *any* use of this chemical. Deleted 11 uses on crops, livestock, home and other buildings.

Methoxychlor –

originally registered for approximately 50 crops, animal and other uses. Recommendation was to retain for 16 uses including crops, dutch elm, uses on cattle, black fly and mosquito control.

Lindane –

previously registered on 33 crops and livestock. Recommended retention for use as a seed treatment, some preplant treatments of soil, in greenhouses, livestock and pets.

While it would be desirable to use lindane in grain storage areas, mills, grain elevators and box cars, etc., this should be held in abeyance until adequate residue data are developed associated with proposed uses.

Similarly, the propensity of lindane to accumulate in food chains of animals, particularly seed-eating birds will have to be clarified. At the moment the available information suggests that the hazard is much less than that associated with other insecticides now used in seed treatment and the excretion rate in other animals is such to suggest a much lower storage in mammals than with dieldrin.

BHC –

only uses to be retained will be on beef cattle and sheep, due to a special requirement in the interior of B.C. The losses here due to tick paralysis are not only in cattle where the severity approaches losses due to blackfly, but also a serious human health hazard is involved.

Heptachlor –

use pattern has reduced gradually in past five years. Recommendation reduces 1971 use pattern from 20 to 10, primarily wireworm seed treatments and some uses on corn, tobacco and ornamentals.

Aldrin –

1969 registration involved uses on 30 crops. Recommendation reduces uses to 10 crops, mainly as wireworm seed treatment, some uses on corn, lawns, turf, ornamentals and home gardens. But aldrin is not likely to be available in some provinces due to provincial regulations (same applies to dieldrin and heptachlor).

Dieldrin –

previously 40 crops, now limited to 7 crops, primarily seed treatments for wireworm control and minor uses on blueberry, strawberry, ornamentals and nursery crops.

Endrin –

originally registered for use on 20 crops. Recommendation limits use to 7 crops mainly for cutworm control on cereals, rape, flax and mustard (no residue basis). This will, of course, be reviewed again when a replacement is available.

Chlordane –

originally 40 crops, now reduced to 15 crops, mainly vegetables, corn, strawberries, lawns, turf and ornamentals for soil insect control. New information. New formulations under development. Large increase in volume of use in 1970 to replace other cyclodiene insecticides. This will require watching due to expanded use in 1970. We expect new formulations in 1971 containing little or no heptachlor. These will have to be reevaluated.

Toxaphene –

are concerned about the lack of modern information pertaining to its properties, persistence and hazard in the environment. No FAO/WHO AD1, no Codex tolerances were recommended by the FAO/WHO Joint Meeting on Pesticide Residues in 1968. Large scale of use in 1970. Was registered for use on approximately 20 crops, livestock, mouse control in orchards. 1971 retain for use for mouse control in orchards and on livestock.

Parathion –

Only 2 of approximately 40 uses deleted. Use on tobacco and peppers to be discontinued. Main reservations here concern occupational hazard, people entering treated areas and lack of information on prospects of environmental hazard (Kentville "graveyard plots" - soil persistence). I am personally concerned over the potential increased use of parathion.

The next stage in this review was consultation with the Food and Drug Directorate, the Canadian Wildlife Service, Department of Fisheries and Forestry, and the pesticide industry. These discussions have now been completed and the new use patterns which will be approved for registration in 1971 are in the process of being distributed by the Plant Products Division of CDA to the trade. The above resume should not be considered official, as the details are to be issued in formal memoranda from Plant Products Division.

We learned a great deal from this review and have established priorities for research in both entomology and chemistry to follow up on the remaining uses of the organochlorine insecticides, particularly methoxychlor, lindane and chlordane.

The other objective of this exercise was to attempt to obtain a clear picture of replacement compounds likely to come into a broader scale of use in 1970 and possible problems associated with their use.

Replacements

Current forecast of materials likely to replace the organochlorines where registered uses will be restricted in 1971 are:

endosulfan, carbaryl, carbofuran, azinophos-methyl, chlordane, methoxychlor, toxaphene, diazinon, lindane, Imidan, parathion, fensulfothion, Dursban, disulfoton, dyfonate, Birlane, trichloronat, phosphalone, Gardona, dichlorvos, ronnel, malathion, coumaphos

Of these and *in addition* to the need to clarify the continued future use of methoxychlor, lindane, chlordane (old and new) toxaphene and parathion, our priorities would be further information on efficacy related to persistence and selectivity, metabolism, degradation and pollution potential for:

endosulfan, fensulfothion, azinophos-methyl, carbofuran, Imidan, Gardona, dyfonate, Birlane, Dursban, trichloronat and phosalone.

Our recent experiences with some of these new pesticides are resulting in an increasingly critical approach. Fonofos, chlorfenvinphos and trichloronat were registered in the last two years for use in soil on a "no residue basis". Experiences at CDA research stations at Charlottetown and London have indicated that there is biologically active persistence of either the parent compound or its metabolites. Similarly, work at Vancouver on carbofuran is developing new information on how this compound should be managed.

An extremely important policy statement has been made to CDA research workers concerned with developing recommendations for pest control. At the 1970 work planning meeting, the Director-General, Dr. B.B. Migicovsky enunciated the view that research which involves the development of recommendations for the control of a pest which involve the introduction of a chemical into the environment *will not be considered complete* until we have developed information on the environmental consequences of the use of the pesticide. While from the practical standpoint we cannot immediately meet this requirement, it will have to be borne in mind in the planning and execution of future research on insect control.

Priorities for Review in 1971

(Registration status and tolerances)

endosulfan	captan
carbaryl	thiram
malathion	folpet
diazinon	metiram
azinphos-methyl	2,4,5-T
dicofol	2,4-D
chlorbenzilate	phenoprop (2,4,5-TP)
perthane	arsenical herbicides
strobane	sodium arsenite
calcium arsenate	hexachlorobenzene*
lead arsenate	quintozene (PCNB)*

*Probably reviewed in 1970

Conclusion

An overview of the situation on public information today suggests a highly unsatisfactory impression of polarization of views between volunteer experts and the apologists for the status quo. The communications media, particularly television, have been responsible for promoting the theatrical performances of some biologists, resulting in the sensational possibilities of the situation being emphasized for public consumption without objective presentations of facts. The truth lies somewhere between the two views. The political decision makers in our governments require all the sound advice that can be provided to them based on the evaluation of scientific evidence by qualified experts, the economic impact of available choices and the social values which the public has not yet decided upon because they cannot "cost-benefit" the choices involved. I would remind members of the Entomological Society of Canada of the President's Address of 1969, Professor A.S. West's "Challenge to Entomologists" and the Science Council of Canada statement in its 1969-70 Report on the "Role of Professional Societies and Scientific Disciplines". But in developing advice to the government - remember that government is the art of the *possible* - in a designated time frame.

Canadian entomologists and scientists in related disciplines should also address themselves to regulations which are now being developed for the new version of the Pest Control Products Act (1969), the Fisheries Act, the Canada Water Act and a new Air Pollution Act which will probably be introduced in 1970. Will these regulations be adequate for the next decade? Our experience in the past 10 years suggests the only way we can build up the ability to predict the behaviour of an insecticide *is to follow up on its introduction to use.* Entomologists will have to collaborate with other disciplines and industry to provide this store of information. Policies will have to be designed to ensure industry participation. We are already into such questions as the necessity for developing criteria for registration of biological control agents such as viruses, bacteria and specialized chemicals such as sex attractants, repellants and chemosterilants. Entomologists will have to assist regulatory agencies in developing and reviewing criteria for performance.

What are the prospects of a practical breakthrough in managing natural control agents in the next decade or two? What changes in insecticide licensing and regulating use will be required to harmonize biological and chemical control? How can the massive problem of biting fly control in Canadian sub-arctic conditions be solved in a practical manner compatible with our new Canadian conscience concerning the northern environment? Canadian entomologists were (and remain) ecologists long before the modern day Jeremiahs discovered the political power of the word "ecology" and "ecosystem". Canadian entomologists are accustomed to the necessity for finding ways and means of providing food and living in a hostile environment. How much of the "web of life" can be insulted by insecticides and to what degree without consequences we cannot accept? These are a few of the questions for which entomologists can provide answers as guidance for governments.

Annually since 1962, the Canada Committee on Pesticide Use in Agriculture, has been stressing the importance of entomologists developing practical guidelines for extension workers and growers on "economic thresholds for insect control". Harcourt (1970) has recently developed "crop life tables as a pest management tool", this in conjunction with his work on developing mathematical models for application of control measures to cabbage insects have demonstrated what can be done to reduce insecticide use and still produce a quality product with good economic returns. I would strongly suggest that we must have reliable information on crop losses and economic thresholds for treatment, not only from the practical standpoint of developing recommendations for control, but also for the purpose of planning priorities for future research. Economic thresholds for treatment are necessary before we can remedy some of the unsatisfactory situations that still persist in some provinces where the farmer is advised to treat on a 3-5 day or weekly basis on an "as necessary" basis.

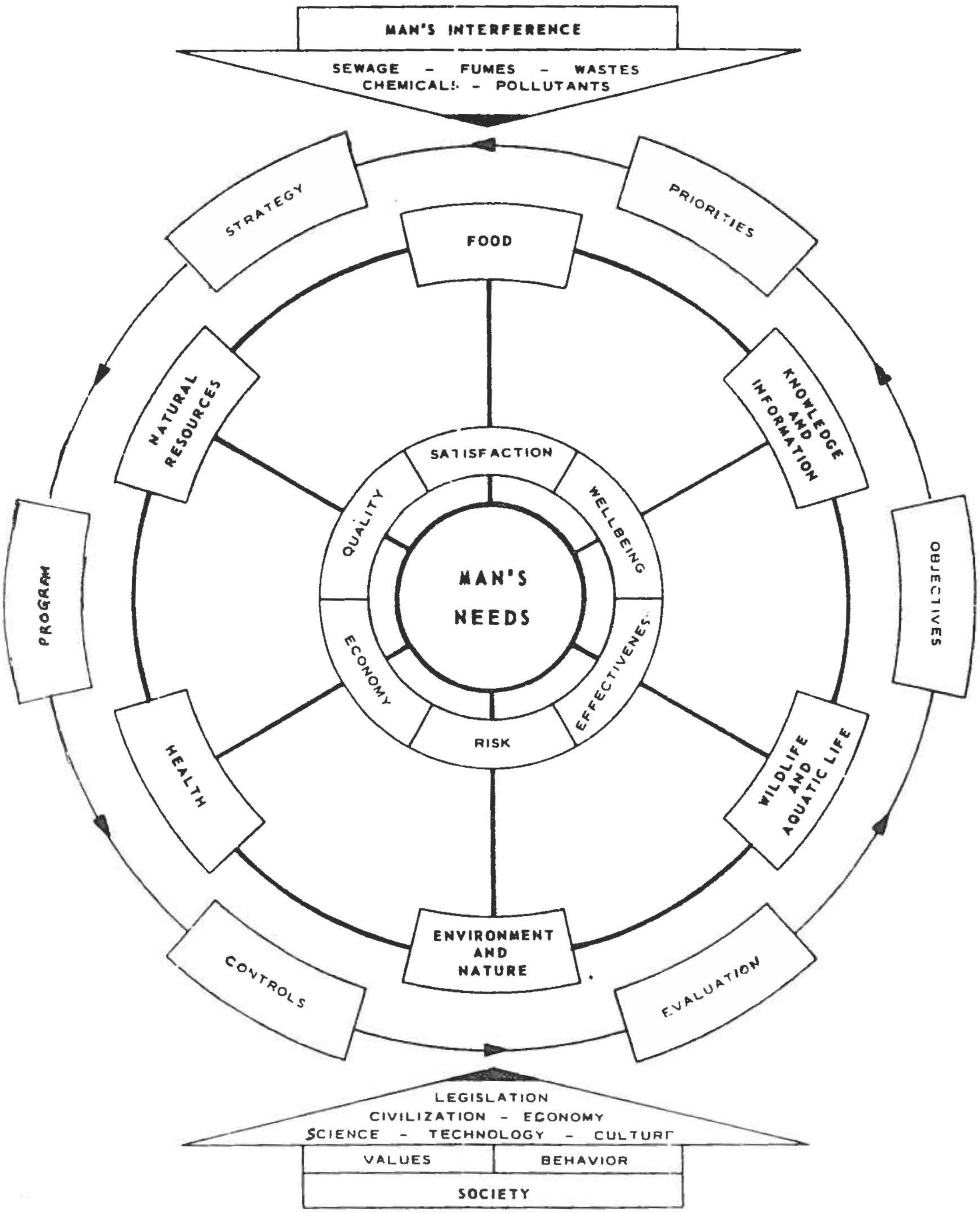
A final word concerning the Canadian pesticide industry.

We are at a disadvantage in Canada compared to the USA, UK, Germany and other countries with a basic pesticide industry. All insecticides used in Canada are imported, our pesticide industry is largely a formulation and marketing industry. While contacts and communication with this industry are good, the fact that the bulk of research on new insecticides prior to registration is carried out outside of Canada, has been a source of concern. Offers to the industry from government to expand collaborative work have not met with much response except in a few exceptional useful cases. This is an area which could and should receive more attention. Governments will be looking to industry for information on product and container disposal in order to avoid the problems created by the mass collection of DDT in some provinces. Industry will also be largely responsible for assistance in developing contingency plans in cases of accidents involving large quantities of pesticides. Manufacturing plant effluent disposals will come under the scrutiny of regional and federal governments and quality control procedures will have to be improved in formulating plants to avoid cross contamination of the formulations offered for sale.

Received August 24, 1970

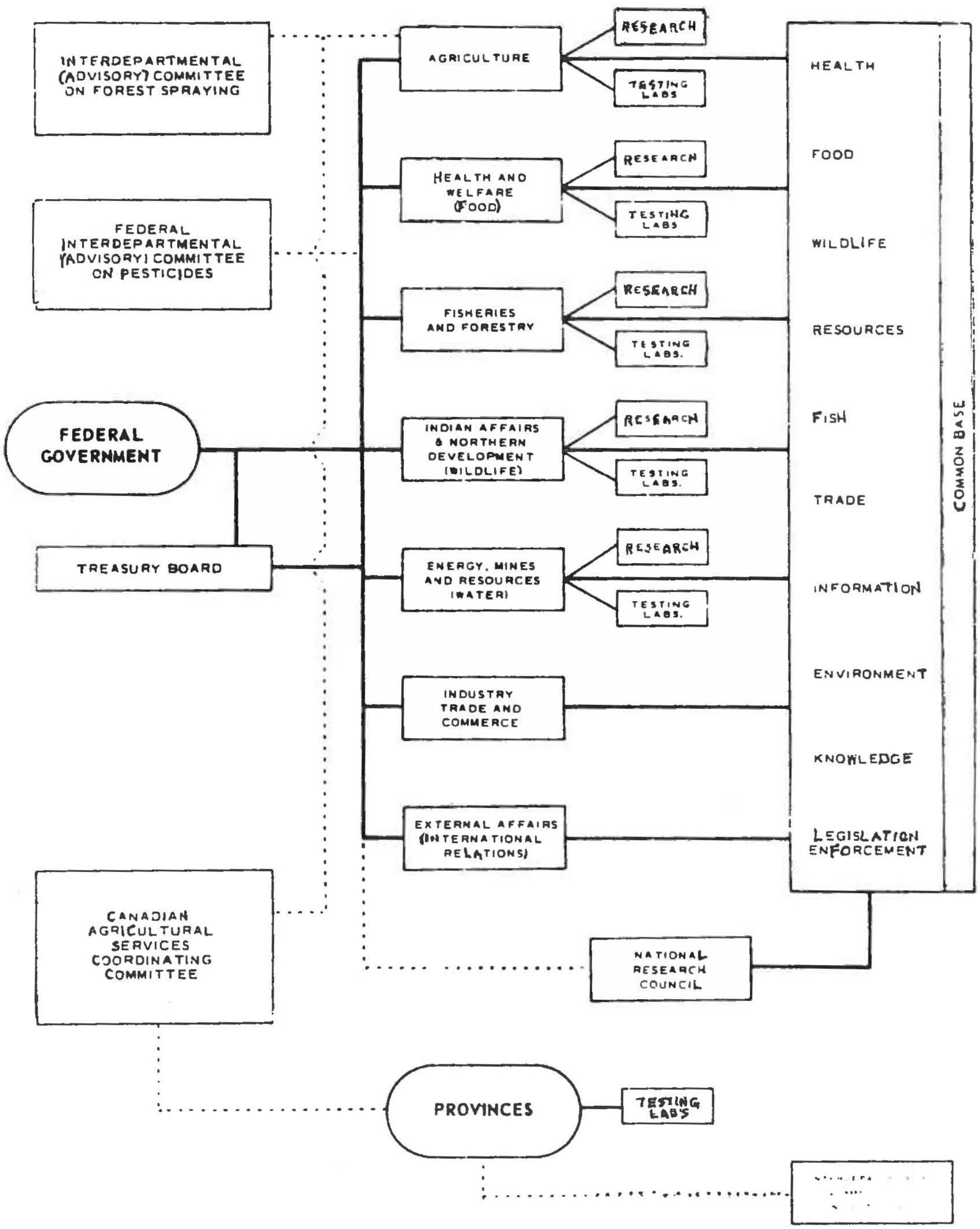
APPENDIX A

MAN'S ENVIRONMENTAL AND RESOURCES MANAGEMENT SYSTEM



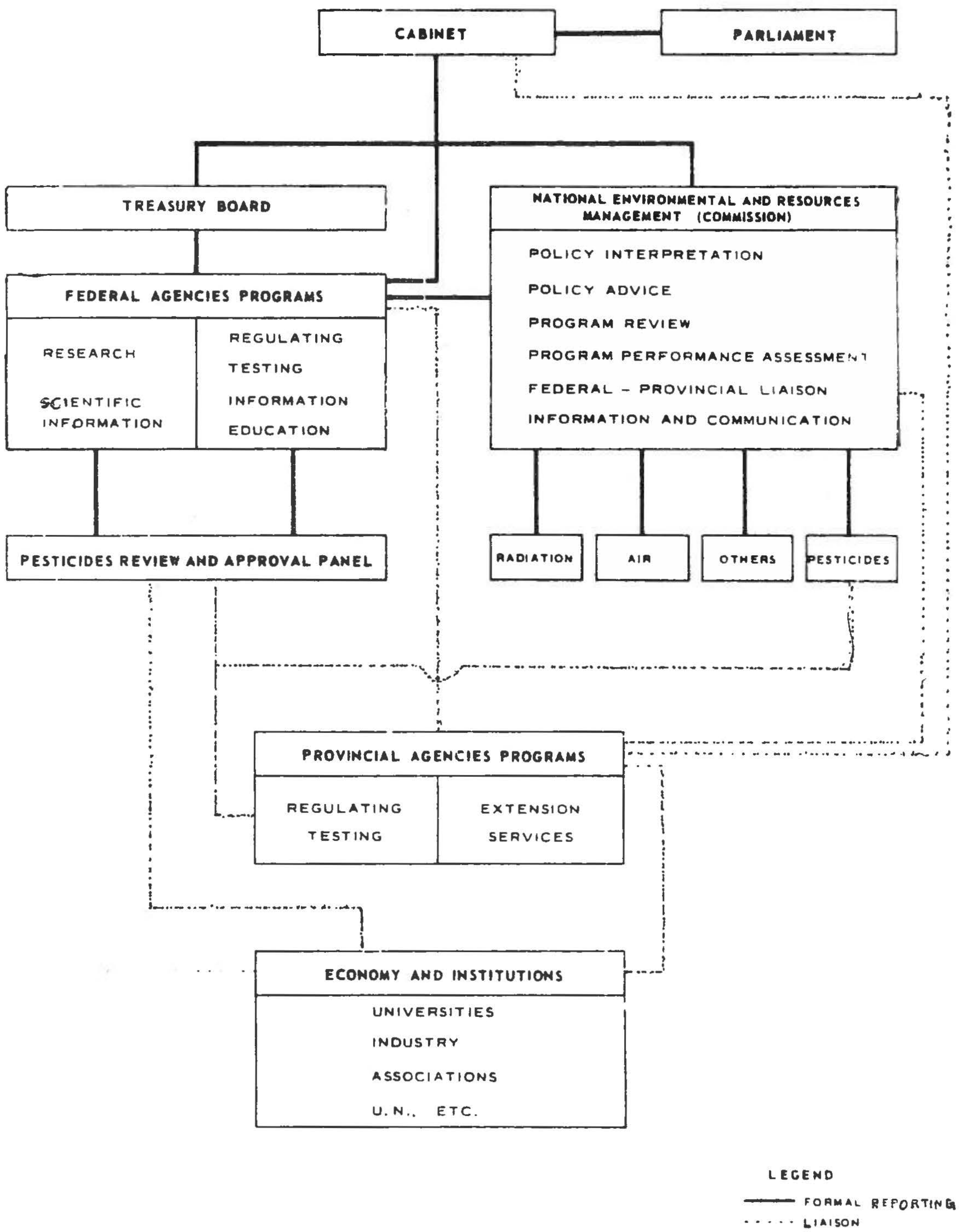
APPENDIX B

DEPARTMENTS CONCERNED WITH PESTICIDES, ENVIRONMENTAL AND HEALTH MANAGEMENT



APPENDIX C

PROPOSED MODEL OF MANAGEMENT ORGANIZATION



EFFECT OF INSECTICIDES IN COMBINATION WITH PHOSPHATE STARTER FERTILIZERS ON SUGAR-BEET ROOT MAGGOT CONTROL AND YIELD OF SUGAR BEETS IN MANITOBA[1]

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ABSTRACT

In 1969 and 1970, late and early adult flights, respectively, of the sugar-beet root maggot, *Tetanops myopaeformis* (Roeder) resulted in heavy root maggot infestations, on test sites. In 1969, satisfactory plant protection resulted from applications of granules containing aldicarb, phorate, trichloronat, and carbofuran; sugar beet yields were increased by 2.0 to 4.0 tons/acre. In 1970, granules of aldicarb, phorate, fonofos, carbofuran, and disulfoton were effective and sugar beet yields were increased 3.0 to 5.4 tons/acre. Granules of these insecticides were not phytotoxic and decreased maggot infestations effectively when used with either liquid or granular phosphate fertilizers. Emulsifiable formulations of several organophosphorus or organocarbamate insecticides applied in liquid phosphate fertilizer were either slightly less effective or too phytotoxic. The capacity of sugar beets to withstand damage by heavy maggot infestations was associated with the relative time of adult activity or maggot establishment and seedling development. Under such heavy maggot infestations, insecticide protection of young seedlings stands is particularly beneficial.

INTRODUCTION

Previous tests in Manitoba showed that carbofuran applied to the seed furrow effectively controlled the sugar-beet root maggot, *Tetanops myopaeformis* (Roeder) and was not phytotoxic (Allen *et al.* 1969). Carbophenothion and ethion also protected sugar-beet stands. Several organophosphorus insecticides, applied in bands above-furrow at seeding, were effective and not phytotoxic, but the high rates of application required were not considered practical for use in Manitoba.

This is a report on tests in 1969 and 1970, when exceptionally heavy root maggot infestations occurred. They evaluated the effectiveness of insecticides applied in conjunction with phosphate "starter" fertilizers released into the seed furrows.

MATERIALS AND METHODS

The insecticides tested for sugar-beet root maggot control are listed in Table 1. Except for compounds listed under experimental numbers, common names are used in the text. Insecticide granules used contained from 5 to 20% active ingredients. Insecticides applied in liquid fertilizer were prepared by the suppliers as emulsifiable concentrates, flowable or wettable powder formulations. Application rates shown in Tables 2 and 3 are in terms of active ingredients per acre of beets.

In general, test plots were arranged in randomized blocks; each plot consisted of four 60-ft. rows. Four outside guard rows were provided for each block. In 1969 and 1970 the

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TABLE 1

Common names, registered names with chemical definition and sources of insecticides.

Aldicarb (Temik) 2-methyl-2-(methylthio) propionaldehyde O-(methylcarbamoyl) oxime, Union Carbide Canada Ltd., Toronto, Ontario.

Bay 77488 phenylglyoxylonitrile oxime O, O-diethyl phosphorothioate, Chemagro, Corp., Kansas City, Mo.

C18244 O-ethyl-O-(2,5-dichloro-4-iodophenyl) ethyl-thiophosphonate, Green Cross (CIBA) Products, Montreal, Que.

Carbofuran (Furadan), Chem. Div. F.M.C. Corp., Middleport, N.Y.

Chlordane AG, Velsicol Chemical Co., Chicago, Ill.

Diazinon, Fisons (Canada) Ltd., Toronto, Ont.

Disulfoton, Chemagro Corp., Kansas City, Mo.

Fensulfothion (Dasanit) Chemagro Corp., Kansas City, Mo.

Fonofos (Dyfonate) Stauffer Chemical Co., Portland, Oreg.

Heptachlor, Velsicol Chemical Co., Chicago, Ill.

N-2596 S-(p-chlorophenyl) O-ethyl ethylphosphonodithioate, Stauffer Chemical Co., Chicago, Ill.

Phorate (Thimet) Cyanamid of Canada, Rexdale, Ont.

Trichloronat (Bay 37289) Chemagro, Corp., Kansas City, Mo.

plots were set up during the third week of May. A 4-row planter equipped with double discs opened furrows 1-in. deep and Monogerm seeds released from seeder boxes were spaced 7 to 10 per ft. of row. Starter fertilizer was applied either as a liquid which was metered into the furrow with a "John Blue" squeeze pump or as a granular material applied from a fertilizer attachment. Phosphoric acid (0-52-0) diluted with water 1:3 (V/V) and Triple superphosphate (0-46-0) were used as liquid and granular sources of phosphate, respectively. Insecticide granules were delivered from cone-seeders and released above the seed as the furrows closed, then lightly covered with soil and firmed by press-wheels. Insecticides in liquid formulation were suspended in diluted starter fertilizer and dispensed into the furrows with the seed.

In 1969, additional fertilizer was applied early in June when a mixture of Triple superphosphate (0-46-0) and Potash (0-0-60) was injected to a depth of 6 in. midway between each set of two rows, to supply P_2O_5 and K_2O at 150 and 117 lb/acre. In mid-June, 1970, Ammonium phosphate (11-48-0) was similarly applied at 100 lb/acre and Ammonium nitrate (34-0-0) was broadcast to supply nitrogen at 80 lb/acre.

In 1969, Experiment 1 evaluated insecticide granules when liquid starter fertilizer (0-52-0) was dispensed into the furrow at 14-gal/acre to supply 30 lb of P_2O_5/acre. Experiment 2 compared the effectiveness of trichloronat, fensulfothion, fonofos emulsifiable concentrates (E.C.) and carbofuran 75% wettable powder (W.P.) suspended in liquid starter fertilizer. Fertilizer solution applied at 9.3 gal/acre supplied 20 lb of P_2O_5/acre. To minimize separation and settling of the insecticides, 6-plots in a row were treated, consecutively.

In 1970, Experiment 3 compared the effectiveness of insecticide granules, when Triple superphosphate (0-46-0) was applied as the starter fertilizer at 24 lb of P_2O_5/acre. In Experiment 4 heptachlor and carbofuran granules were compared with emulsifiable formulations of phorate, fonofos and carbofuran flowable(FL.). The granules were applied after the liquid starter fertilizer was dispensed, while the other formulations were emulsified in liquid fertilizer which in all tests was applied at 20 lb of P_2O_5/acre. Plots were treated in the order outlined for Experiment 2. In Experiment 5 the effectiveness of carbofuran granules, applied at 0.75 lb/acre, was compared over 5 dates of seeding from May 21st to June 15th. On each date, treated and untreated plots were paired and replicated 4 times. Triple superphosphate (0-46-0), as applied in Experiment 3 was used as starter fertilizer.

Seedling stands on each plot were evaluated by counting the number of beet-containing inches on two 100-in. lengths of row. Stands after thinning were estimated by counting the beets on two 25-ft. lengths from the central rows of each plot. These data were not tabled but are briefly considered in the section on phytotoxicity. The pattern of adult flights was determined by using water traps as described by Harper and Story (1962). Root maggot infestations were estimated on each plot in early September by counting the maggots in 10 soil samples, each 8-in. square and 14-in. deep. Each sample was centered on a beet in the outside row.

The numbers and yields of beets were determined in early October, when roots from two 50-ft. lengths of the central rows of each plot were counted and weighed. In 1970 the number of damaged roots was also recorded. This damage is indicated by the growth of secondary roots, which results when root maggots cut the tap-root early in the growing season (Harper *et al.* 1961).

All data were examined by analysis of variance and the multiple range test (Duncan 1955); significance was tested at the 1% level unless otherwise indicated.

RESULTS

Adult Flight Patterns and Maggot Infestations

In 1969 and 1970, adults had started to emerge from the soil by June 5th. In 1969, cold weather from June 10th to 22nd delayed active oviposition until June 24th and the peak of adult flight until June 30th. Meanwhile the beets seeded on May 21st were well established and the heavy maggot infestation which developed did not cause either malformation of roots or loss of plants on untreated plots. Because of the delay in maggot establishment only 67% of the maggots reached full development by the first week in September.

In comparison, adult flight was exceptionally early in 1970 and peak flight and oviposition had occurred by June 9th. Also at peak flight 3 times more adults were trapped than in 1969. Untreated plots suffered a severe loss of plants and extensive root damage. Moreover by late August 87% of the maggots were fully developed. However, the number of maggots recovered from the untreated plots at that time was considerably lower than in the preceding year (Tables 2 and 3).

Phytotoxicity

Experiments 1 and 2. Stands of beets, before and after thinning, were not affected by the insecticide granules or formulations applied in liquid fertilizer. Stands of harvested beets were complete on all treated and untreated plots (Table 2).

TABLE 2

Effect of insecticides and formulations applied in combination with phosphate starter fertilizer on maggot control, and yield at Plum Coulee, Manitoba, 1969.

Insecticide	Toxicant (lb/acre)	Maggots per beet	Control (%)	Harvested beets: Number per 100 row ft.	Harvested beets: Weight (lb/beet)	Harvested beets: Yield (tons/acre)
Experiment 1 (6 replicates)						
Liquid fertilizer (0-52-0) applied to furrow						
Aldicarb 10G.	1.5	17.5a[1]	75	95[2]	1.27a	14.2a
	1.0	21.6ab	69	98	1.16ab	13.5ab
Phorate 10G.	1.0	29.9ab	58	99	1.06bc	12.3bc
Trichloronat 15G.	1.0	30.5ab	57	91	1.16ab	12.5bc
Carbofuran 10G.	0.75	33.7ab	52	96	1.11ab	12.5bc
Fonofos 15G.	1.0	35.2b	50	95	0.99bc	11.1cde
Fensulfothion 10G.	1.0	37.5b	47	94	1.05bc	11.6cde
	0.75	37.8b	46	94	1.08abc	12.0bcd
C18244 5G.	1.0	55.1c	22	94	1.04bc	11.5cde
Bay 77488 10G.	1.0	57.9c	18	89	0.98bc	10.4de
Heptachlor 20G.	1.0	71.6c	0	101	0.88c	10.5de
Untreated		70.4c		99	0.87c	10.2e
Experiment 2 (6 replicates)						
Insecticide in fertilizer (0-52-0) applied to furrow						
Carbofuran W.P.	1.0	19.2a	66	102[2]	1.00b	12.1a
Fensulfothion E.C.	1.0	35.3b	37	99	1.10a	12.9a
Trichloronat E.C.	1.0	36.8b	34	98	0.93bc	10.8bc
Fonofos E.C.	1.0	39.5b	29	95	0.98b	11.1b
Untreated		55.9c		99	0.84c	9.8c

1 Means followed by the same letters not significantly different at 1% level (Duncan 1955).
2 Differences between means not significant.

Experiment 3. Initial seedling stands were reduced 16% by fonofos or disulfoton at 1.0 and 1.25 lb/acre, respectively, and 28% by diazinon at 1.25 lb/acre. Stands after thinning and at harvest were not affected by that degree of phytotoxicity.

Experiment 4. Carbofuran and heptachlor granules were not phytotoxic to beet stands before or after thinning. However, emulsifiable formulations of carbofuran and fonofos applied in liquid phosphate fertilizer each reduced initial stands 53%, and phorate resulted in a 60% loss. These losses reduced stands significantly ($P<0.01$) after thinning and resulted in lower yields than obtained with carbofuran granules (Table 3).

TABLE 3

Effect of insecticides and formulations applied in combination with granular and liquid phosphate starter fertilizers on maggot control, and yield at Plum Coulee, Manitoba, 1970

				Harvested beets			
Insecticide	Toxicant (lb/acre)	Maggots per beet	Control (%)	Number per 100 row ft.	Weight (lb/beet)	Root damage (%)	Yield (tons/acre)
			Experiment 3 (6 replicates)				
			Granular fertilizer (0-46-0) applied to furrow				
Aldicarb 10G.	1.0	10.1a[1]	75	76[2]	1.90a	5.6a	16.7a
Phorate 10G.	1.0	11.1a	72	79	1.63ab	7.5a	15.3ab
Diazinon 5G.	1.25	14.9ab	63	77	1.83a	10.7a	16.6a
Fonofos 10G.	1.0	15.2ab	62	81	1.62ab	16.8abc	15.3ab
Disulfoton 15G.	1.25	15.5ab	61	77	1.61ab	14.3abc	14.3b
Carbofuran 5G.	1.0	17.2ab	57	86	1.63ab	6.4a	16.6a
Trichloronat 15G.	1.0	17.6ab	56	83	1.63ab	11.2ab	16.0ab
Carbofuran 10G.	1.0	19.6ab	51	85	1.66ab	7.3a	16.5a
N-2596 10G.	1.0	24.6b	39	91	1.43bc	18.1abc	15.5ab
Chlordane 10G.	1.25	43.0c	0	78	1.35bc	24.5bc	12.5c
Heptachlor 20G.	1.0	44.9c	0	84	1.21c	18.5abc	12.1c
Untreated		40.1c		67	1.40bc	24.9c	11.3c
			Experiment 4 (6 replicates)				
			Liquid fertilizer (0-52-0) applied to furrow				
Carbofuran 10G.	1.0	20.1bc	46	80a	1.67bc	11.0ab	15.9a
Heptachlor 20G.	1.0	42.2d	0	70b	1.33d	27.3cd	11.2c
			Insecticide in fertilizer (0-52-0) applied to furrow				
Phorate E.C.	1.0	9.0a	76	63bc	1.79b	12.8ab	13.3b
Carbofuran FL.	1.0	12.3ab	67	58c	2.08a	6.3a	14.2b
Fonofos E.C.	1.0	21.0c	44	61bd	1.88ab	19.3bc	13.7b
Untreated		37.3d		64bc	1.45cd	28.1d	11.0c

1 Means followed by the same letters not significantly different at 1% level (Duncan 1955).

2 Means of 83 or over were significantly different than the untreated plots at the 5% level.

Experiment 5. Carbofuran granules, applied at 0.75 lb/acre in combination with granular phosphate fertilizer on 5 dates, were not phytotoxic. Initial seedling stands and stands after thinning were complete.

Maggot Control and Damage

Experiment 1. The heavy root maggot infestation present in 1969 was reduced significantly by furrow applications of aldicarb, phorate, trichloronat and carbofuran granules (Table 2). Since the beet stands at harvest were complete, these reductions in numbers of maggots were associated with increases in weight per beet, and yields were increased by 2.0 to 4.0 tons/acre over untreated controls. While fonofos and fensulfothion also reduced maggot populations significantly and stands at harvest were complete neither weight per beet nor yields were increased. Granules of C18244, Bay 77488 and heptachlor did not control maggots or improve yields.

Experiment 2. Carbofuran wettable powder applied in starter fertilizer reduced maggot infestation significantly and increased yield by 2.3 tons/acre (Table 2). Emulsifiable formulations of fonofos and fensulfothion were less effective than carbofuran for root maggot control. However, yield increases were again associated with increased beet weight and the fensulfothion treatment increased yield by 3.0 tons/acre.

Experiment 3. All the organophosphorus and organocarbamate insecticide granules tested reduced maggot infestations by 40 to 75% (Table 3). The treatments resulted in yield increases of 3.0 to 5.4 tons/acre, because they minimized early maggot damage to the roots, protected beet stands generally and increased beet weight. Alternatively, on the untreated plots 24% of the beets were destroyed by maggots during the growing season; the remaining beets were small and a quarter of them had damaged roots. It is notable that carbofuran 5 and 10% granules formulated on ground corn cob and sand-core, respectively, gave similar results and that differences between fonofos and N-2596 were not significant. Heptachlor and chlordane gave no control.

Experiment 4. Carbofuran granules applied along with liquid phosphate fertilizer gave acceptable crop protection and increased yield by 4.9 tons/acre (Table 3). Heptachlor granules again were non-effective. Carbofuran and phorate, which were very phytotoxic, provided good maggot control and protected the remaining beets from root damage. The poor beet stands harvested after use of these insecticides and fonofos resulted in lower yields than obtained with carbofuran granules. On the untreated plots, maggots destroyed 19% of the beets during the growing season and more than a quarter of those remaining suffered root damage.

Experiment 5. On each of 5 seeding dates, untreated plots and those treated with carbofuran at 0.75 lb/acre were compared (Figure 1). For the criteria shown the overall differences between the treated and untreated plots were significant at the 1% level. Results for the first 4 seeding dates indicate that the beet stands were protected by carbofuran from early root damage and throughout the growing season. Beet weights were increased and yield increases of 4.6 to 5.9 tons/acre were recorded. The numbers of maggots estimated on the untreated plots for these seeding dates are probably low. Beet stands from thinning (June 24th) to harvest were reduced 21 to 39% and therefore, large numbers of maggots may not have survived. This may explain why the maximum maggot reduction, attributed to treatment, was only 35%.

The reduction in maggot population shown for the June 15th seeding appears reasonable because adult flight was relatively light when the seedling stand became established. Similarly the stand harvested suggest that important crop damage did not occur. It is therefore surprising, that such wide differences were observed in root damage, weight per beet and yield.

DISCUSSION

Previous tests (Allen *et al.* 1969) indicated that in-furrow applications of carbofuran at 0.75 to 1.0 lb/acre reduced root maggots by 75 to 85% and were as effective as heptachlor at 1.0 lb/acre. In these tests heptachlor gave adequate maggot control and plant protection, and was used as a standard for evaluating the effectiveness of other toxicants. When heavy root maggot infestations occurred in 1969 and 1970 carbofuran at 1.0 lb/acre, only reduced

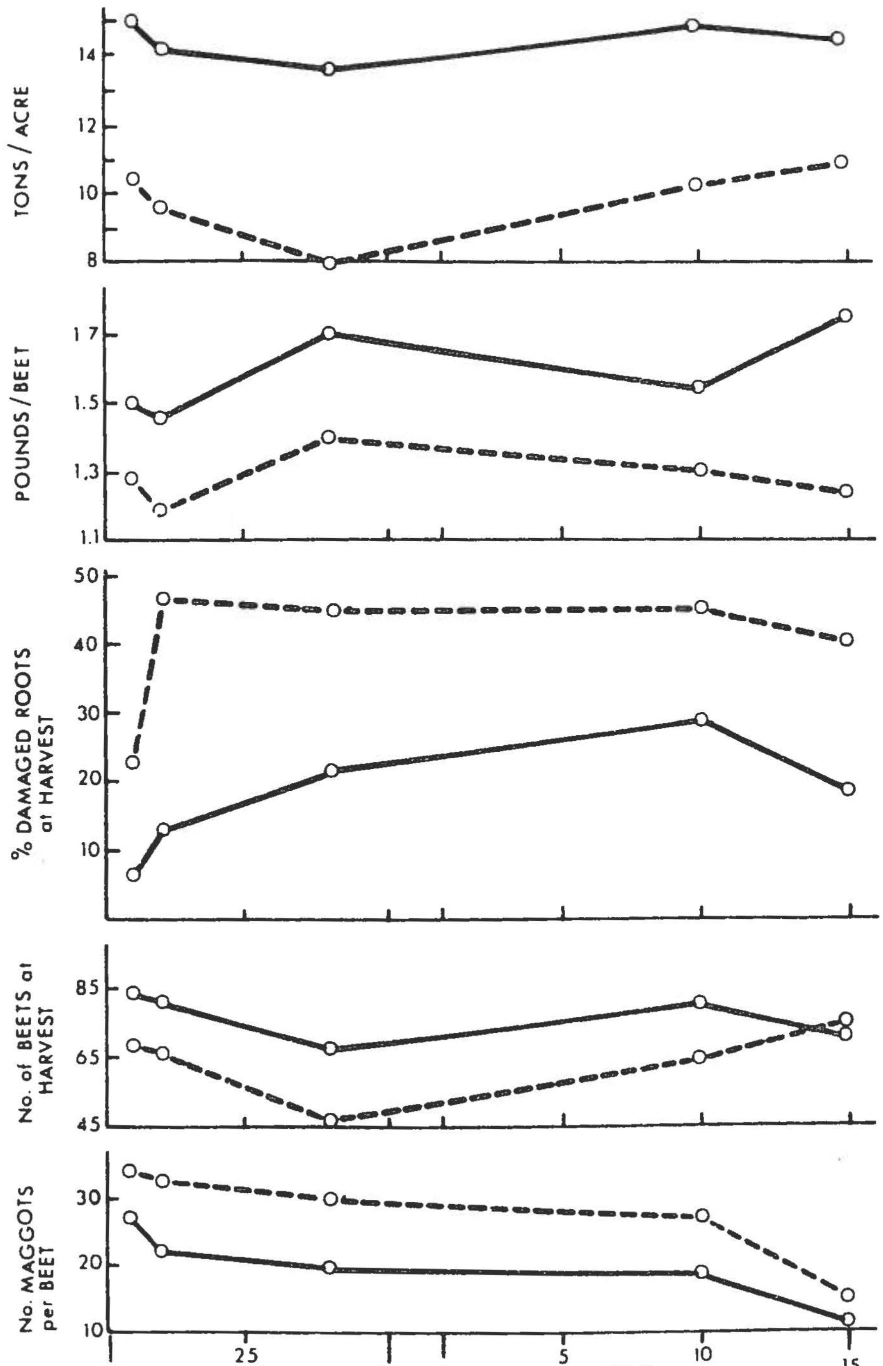

Figure 1. Comparison of criteria concerned with yield on untreated (broken line) and carbofuran treated (solid line) plots, set up on various seeding dates.

maggot infestation 46 to 67% in comparison to untreated plots. In these years aldicarb gave about 70 and 75% maggot control, respectively. The organophosphorus insecticides tested gave relatively low levels of control. Heptachlor and chlordane provided no control or plant protection, indicating resistance of the sugar-beet root maggot to these insecticides.

There was no clear evidence that phosphate starter fertilizers affected the level of control because insecticide granules performed as well when liquid or granular sources of phosphate were applied to the seed-furrows (Experiments 1, 3, and 4). However, the effectiveness of fensulfothion, trichloronat and fonofos may have decreased to some extent when they were applied in liquid phosphate fertilizer (Experiment 2). This was not true for the wettable powder formulation of carbofuran. However, the severe phytotoxicity experienced when carbofuran, phorate and fonofos were applied in the same way suggests that such an application procedure is unacceptable.

In 1969, effective crop protection resulted when insecticides reduced maggot populations to between 17.5 to 34.0 maggots/beet; beet stands harvested were virtually complete and yields were increased by 2.0 to 4.0 tons/acre. The beets withstood such infestations during the growing season because the late adult flight allowed the seedlings more than 5 weeks to establish before heavy oviposition and maggot infestation occurred.

In 1970 the situation differed, adult flight was exceptionally early, and seedlings were less than 3 weeks old when heavy oviposition occurred. The beets suffered extensive root damage and stand was lost (Table 3) as the maggot infestation developed. Insecticides that reduced infestation to between 10.0 to 25.0 maggots/beet increased beet weight, and yields by 3.0 to 5.4 tons/acre even though wide variation in stand losses were observed between replicated plots.

While the adult flight was early in 1970 and 3 times heavier than recorded in the preceding year, a corresponding increase in maggot infestation did not result. Perhaps the 4.5 in. of rain between June 9th and 11th, just before peak flight, reduced the number of young maggots that established. Also the maggot population available for sampling in late August may have diminished because many heavily infested beets were killed on untreated plots during July.

Clearly, the capacity of sugar beet crops to withstand damage and benefit from protection due to insecticide use, varies from year to year. This capacity is affected by the relative time between adult flight, maggot establishment and stage of development attained by a seedling stand. In 1970, successive plantings benefited from such protection and even the latest planting required protection for at least 3 weeks because moderate adult activity continued until July 10th. Furthermore, beets sown and treated May 21st with aldicarb, carbofuran and several organophosphorus insecticides appeared, August 6th, to have large roots and luxuriant foliage with excellent color. In contrast, those on untreated plots or on plots treated with heptachlor or chlordane had smaller roots, and yellowed foliage, in spite of an adequate supply of nitrogen fertilizers.

We conclude that root maggot infestations and the capacity of sugar beets to withstand damage vary from year to year. However, when moderate to heavy maggot infestations occur, insecticides that provide adequate plant protection, increase yields and more than offset the cost of control.

ACKNOWLEDGEMENTS

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REFERENCES

Allen, W.R., W.L. Askew, and M. Klassen. 1969. Effect of insecticides and application procedures on phytotoxicity to sugar beet seedlings and control of sugar-beet root maggot. Man. Ent. 3: 70-78.

Duncan, D.B. 1955. Multiple range and multiple F tests. Biometrics 11: 1-42.

Harper, A.M., C.E. Lilley, and P. Bergen. 1961. An evaluation of insecticides for control of the sugar-beet root maggot in southern Alberta. J. Amer. Soc. Sugar Beet Technol. 11: 485-490.

Harper, A.M. and T.P. Story. 1962. Reliability of trapping in determining the emergence period and sex ratio of the sugar-beet root maggot, *Tetanops myopaeformis* (Roeder) (Diptera: Otitidae). Can. Ent. 94: 268-271.

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DDT RESIDUES IN SOIL IN THE WINNIPEG AREA[1]

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ABSTRACT

An analysis of DDT residues was conducted on soils, where DDT had been applied for mosquito control for eight or more consecutive years at 1 lb a.i./acre. Residues recovered from the top ½ inch of soil plus the overlying vegetation ranged from 13 to 39 (mean 26.5) ppm DDT plus metabolites. Bonding and inactivation of DDT by soil was demonstrated by the successful utilization of pools by mosquitoes, where bottom soil residues averaged 23.72 ppm DDT.

INTRODUCTION

A matter of major concern to ecologists, conservationists and the public in general is the persistence of DDT in the environment and its dispersal by water, soil erosion and biological organisms in which the residues accumulate. There may also be biological magnification (Woodwell 1967, Dimond *et al.*1970) in successive levels of food chains with high and potentially harmful amounts of residue occurring in species near the top of the food chains. Edwards (1964) found that DDT was more persistent in soil than any other insecticide tested; 80% remaining after one year and 50% after three years. Soil animal populations were altered for months after the bulk of the residue had disappeared. Nash and Woolson (1967) found that the average time for half of the original amount of DDT to disappear from soil was 10.5 years (range 2.5-35).

Since DDT has been used in the Winnipeg area for mosquito control from 1947-1969, some soils have undoubtedly accumulated substantial residues. The purpose of the following study was to establish how much residue was present in the top ½ inch of soil plus the overlying vegetation in areas where annual aerial or ground treatments of 1 lb a.i. (active ingredient) DDT per acre had been applied for at least eight years.

METHOD

The top ½ inch of soil plus the overlying vegetation was removed for quantitative analysis of DDT residues. A total of 1 lb dry weight (air dried at 25°C) was collected per sample during June 1968. Each sample consisted of 75-100 circular plugs cut 1 inch in diameter using a sharpened cork borer. The tube was punched through the vegetation and was set to penetrate ½ inch into the soil. The plugs contained the vegetation layer plus soil. Each sample was collected over an area of approximately 1/5 of an acre, and composited to be representative. The samples were taken to our Winnipeg laboratory, dried and packaged for shipment to the analysis laboratory in Ontario.[2]

[1] Research supported by the Metropolitan Corporation of Greater Winnipeg. By prior agreement, R.D. Dixon (see references) was permitted to use the table of results in his M.Sc. Thesis.

[2] Ontario Research Foundation, Sheridan Park, Ontario.

The soil in each sample was thoroughly mixed, screened and then sub-sampled for analysis. The subsample (20 gms) was double extracted with 10% acetone in hexane. The combined extracts were cleaned-up with charcoal and Florisil adsorbents. The cleaned-up extracts were then analysed by gas liquid chromatography with an electron capture detector. Thin layer chromatography was used to confirm the results.

The vegetative sample (4A) was double extracted with acetonitrile and the residues partitioned into n-hexane and cleaned-up with charcoal and Florisil adsorbents. The remainder of the analysis was the same as for soil.

The recovery of known quantities of pesticides was complicated by the high concentration of residues present in the samples. However, previous experiments with control samples containing little or no pesticides gave the following percent recoveries: DDE 93% in soil, 91% in vegetation; op[1]-DDT 76% in soil, 70% in vegetation; pp[1]-DDT 79.6% in soil, 80.5% in vegetation. [3] The values reported in the table of results have not been corrected for recovery.

RESULTS

The amount of DDT plus metabolites is given in Table 1. Samples 1, 2 and 3 were collected from wooded areas, where aerial treatments of DDT (granular formulation) had been applied for eight or more successive years at 1 lb a.i./DDT/acre. Samples 4, 5 and 6 were collected from grassland areas where ground treatments of DDT (fuel oil formulation) had been applied for a similar period at 1 lb a.i./acre. Sample 4 was divided into two parts for the residue analysis: 4A - consisted of a 1 inch vegetative layer (dead grasses) which had accumulated over the years; 4B - consisted of the underlying soil to a depth of ½ inch. As can be seen from Table 1, 81% of the total residue was recovered from the vegetative layer.

The baseline sample (7) was collected at The University of Manitoba Research Station at Glenlea. No known applications of DDT had been made in the area where the soil was collected. The analysis (Table 1) of the unmarked sample confirmed our hypothesis that DDT was absent. Two more specially prepared samples were submitted to the analysis laboratory: samples 8 and 9 from Glenlea had been treated with 12 lbs and 15 lbs a.i./acre respectively, six months prior to collection. The total DDT residue recovered from these unmarked samples was 96.27 ppm and 125.4 ppm respectively. The amount applied was calculated to be 110-120 ppm and 145-155 ppm respectively, or 83% recovery. The treated plots were small pools identical to those described by Dixon and Brust (1971).

DISCUSSION

The pp[1]-DDT and DDD fractions are insecticidally active against mosquitoes and other insects. The op[1]-DDT and DDE are nearly inactive to insects, but DDE is one of the chemicals responsible for thin egg shells in some species of birds (Ratcliffe 1967; Hickey and Anderson 1968). Technical DDT, as produced by the manufacturer, normally contains 65-80% pp[1]-DDT; 15-21% op[1]-DDT and up to 4% DDD (Metcalf, Flint and Metcalf 1962). DDE is a metabolic or degradation product, and it is interesting that over the years only a small proportion of the DDT was converted to DDE in the Winnipeg soils, which emphasizes the persistent nature of DDT in soil.

Sample 5 (Table 1) was taken from a temporary pool where *Aedes vexans* (Meigen) larvae were found in late May 1968. Larvae developed to maturity in a pool where a subsequent residue analysis (June 1968) revealed bottom soil residues contained 23.72 ppm DDT plus metabolites. Some instar IV larvae from this pool were tested for DDT resistance. The LC_{95} was 0.004 ppm, indicating no resistance. Apparently soil bonds and inactivates DDT (Harris, 1966), and even flooded areas contain biologically inactive residues.

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3 **Data supplied by Dr. L.M. Reynolds at the Analysis Laboratory.**

TABLE 1

DDT Residues in Soil and the Overlying Vegetation

Sample (a) Number	Organochlorine residues in p.p.m. (oven-dry weight) (b)				
	DDE	DDD	p.p.1- DDT	o.p. 1- DDT	Total Residue
1	2.77	1.07	29.90	5.31	39.05
2	1.26	0.80	8.87	2.00	12.93
3	0.93	0.67	23.10	2.74	27.44
4A(c)	1.36	0.65	19.10	2.97	24.08
4B	0.86	0.08	3.62	0.88	5.44
5	1.08	1.08	17.71	3.85	23.72
6	2.80	0.91	11.10	2.60	17.41
7	0.005	0.001	0.03	0.01	0.05
8	6.83	2.44	66.60	20.40	96.27
9	4.40	4.90	88.40	27.70	125.40

(a) Location of samples

1. 300 yds south of Wilkes Ave., ¼ mile west of Kenaston St. - Tuxedo.
2. 400 yds west of Kenaston St., 1 mile south of Wilkes Ave. - Tuxedo.
3. ½ mile north of Wilkes Ave., 300 yds west of Shaftesbury St. - Tuxedo.
4. 200 yds west of Waverley St., north side of Wilkes Ave., south of CN tracks - Winnipeg.
5. Roadside ditch, east side of Waverley St., 2 miles south of Permieter Highway - Fort Garry.
6. 200 yds east of Waverley St., north of Asquith Ave., south of CN tracks - Winnipeg.

7, 8 and 9. University of Manitoba Glenlea Research Station. Samples 8 and 9 received known quantities of DDT. Sample 7 was a baseline sample.

(b) Analysis sensitive to 0.001 ppm. The results in the table have not been corrected for recovery.

(c) Sample 4A consisted of the overlying vegetation; sample 4B of the soil directly below.

Harris and Sans (1969) have shown that DDT residues in uncultivated sandy loam soils are retained largely within the top 6 inches, but detectable residues were recovered down to 12 inches. Penetration of DDT in uncultivated Red River clay soils is not known, but residues reported from the top ½ inch in this study undoubtedly represent only a portion of the total. However, it is possible that 90-95% of the DDT present will be in the top 3 inches of the soil (C.R. Harris, personal communication).

The amount of DDT residue in the Winnipeg soils has not caused a problem to date, as far as is known, but it could become a problem if it is being passed up the food chain. Biological magnification has been reported elsewhere by Woodwell *et al.*(1967), Dimond and Sherborne (1969), Edwards (1969) and Dimond *et al.*(1970). The type of food chain magnification one might expect from the Winnipeg soils would be via subterranean invertebrates (earthworms, slugs, etc.) to birds which prey on them, or via small rodents which feed in the area to raptorial birds that prey on them. Food chain magnifications in low lying areas of Winnipeg, where DDT applications have been most commonly made to control mosquitoes, is not likely to occur for some time since at present these areas have a meager invertebrate fauna. Some of the wooded areas, where aerial applications of DDT were carried out annually, are on higher ground and these may present a potential hazard. These areas harbor a substantial invertebrate, small rodent, and bird fauna.

Through the very nature of mosquito developmental sites, the majority of the DDT applications have been made in low lying areas where little or no runoff occurs. It is not anticipated that the DDT residue in Winnipeg will be carried into rivers or streams. DDT bonds readily to clay soils and unless both are transplanted it should remain until it is degraded and/or metabolized. However, more thorough sampling of Winnipeg soils is needed to establish the residue levels over a wide range of treated and untreated soils. Too little is known to assess accurately the hazards of the residue levels found in this study.

ACKNOWLEDGMENT

R.D. Dixon's help in selecting the sites to be sampled is gratefully acknowledged.

REFERENCES

Dimond, J.B., G.Y. Belyea, R.E. Kadunce, A.S. Gatchell and J.A. Blease. 1970. DDT residues in robins and earthworms associated with contaminated forest soils. Canad. Ent. 102: 1122-1130.

Dimond, J.B. and J.A. Sherborne. 1969. Persistence of DDT in wild populations of small mammals. Nature 221: 486-487.

Dixon, R.D. 1969. Ecology of mosquito larvae in the Winnipeg area and evaluation of insecticides for future use in mosquito control. M.Sc. Thesis, University of Manitoba, 191 pp.

Dixon, R.D. and R.A. Brust. 1971. Field testing of insecticides used in mosquito control, and a description of the bioassay technique used in temporary pools. J. Econ. Ent. 64: 11-14.

Edwards, C.A. 1964. Factors affecting the persistence of insecticides in soil. Soils and Fertilizers 27: 451-454.

____1969. Soil pollutants and soil animals. Sci. Amer. 220: 88-99.

Harris, C.R. 1966. Influence of soil type on the activity of insecticides in soil. J. Econ. Ent. 59: 1221-1225.

Harris, C.R. and W.W. Sans. 1969. Vertical distribution of residues of organochlorine insecticides in soils collected from six farms in Southwestern Ontario. Proc. Ent. Soc. Ont. 100: 156-164.

Hickey, J.J. and D.W. Anderson. 1968. Chlorinated hydrocarbons and eggshell changes in raptorial and fish-eating birds. Science 162: 271-273.

Metcalf, C.L., W.P. Flint and R.L. Metcalf. 1962. Destructive and useful insects. Their habits and control. McGraw-Hill Book Co., New York.

Nash, R.G. and E.A. Woolson. 1967. Persistence of chlorinated hydrocarbon insecticides in soils. Science 157: 924-927.

Ratcliffe, D.A. 1967. Decrease in eggshell weight in certain birds of prey. Nature 215: 208-210.

Woodwell, G.M., C.F. Wurster and P.A. Isaacson. 1967. DDT residues in an east coast estuary: a case of biological concentration of a persistent insecticide. Science 156: 821-823.

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TRITICALE AS A NEW HOST FOR STORED GRAIN INSECTS[1]

by M.G. Dolinski,[2] Wm. Hanec[3] and S.R. Loschiavo[1]

A bin in a wooden barn at The University of Manitoba Field Station, Glenlea, Manitoba, containing approximately 150 bushels of triticale was sampled for stored grain on November 26, 1970. The species of insects and numbers of each species recovered from the samples are recorded in Table 1.

TABLE 1

Species and numbers of stored grain insects infesting Triticale, at Glenlea, Manitoba, November 26, 1970.

Species	No. of insects	
	Adults	Larvae
Cryptolestes ferrugineus (Steph.) Rusty grain beetle	386	745
Tribolium castaneum (Herbst) Red flour beetle	18	–
Cephalonomia waterstoni (Gahan) *	11	–
Lathridius minutus (L.) Squarenosed fungus beetle	4	–
Ahasverus advena (Waltl.) Foreign grain beetle	3	–

* Parasite of rusty grain beetle

These results show that triticale can be a host for several common stored grain insects in Manitoba.

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MYODOPSYLLA INSIGNIS (SIPHONAPTERA: ISCHNOPSYLLIDAE) IN MANITOBA

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On 1 August 1967, a male little brown bat, *Myotis l. lucifugus* (Le Conte), was captured by S.L. Iverson near Pinawa, Manitoba. Two male fleas identified as *Myodopsylla insignis* (Rothschild) were collected from this specimen. Buckner (1964) included this flea in the hypothetical list for Manitoba on the grounds that it is a common parasite of bats and has been collected both east and west of Manitoba. The two specimens reported herein, Numbers 1002 and 1003 of the author's collection, provide firm records of the occurrence of *M. insignis* in Manitoba, and brings to 40 the number of species of Siphonaptera now known to occur in the province (Buckner 1964, Buckner and Blasko 1969).

REFERENCES

Buckner, C.H. 1964. Fleas (Siphonaptera) of Manitoba mammals. Can. Ent. 96: 850-856.

Buckner, C.H. and G.G. Glasko. 1969. Additional range and host records of the fleas (Siphonaptera) of Manitoba, Man. Ent. 3: 65-69.

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PARASITES OF A RED-TAILED HAWK

by C.H. Buckner[1] and T.V. Cole[2]

On 23 July, 1969 a young red-tailed hawk, *Buteo jamaicensis*, was captured in Bird's Hill Provincial Park near Winnipeg, Manitoba. The ears of the bird were infested with dipterous maggots which were removed and reared. The adult parasites emerged from their puparia on 8 August, 1969. Three of these, all females, were later identified as *Protocalliphora* sp., the larvae of which are normally found in bird nests where they feed upon nestlings. After all the parasites were removed, the host evidently recovered and exhibited no serious ill effects, although when it was captured it was almost comatose.

Identity of the parasites was confirmed by G. Shewell, Entomology Research Institute, Canada Department of Agriculture, Ottawa. Species identification was not possible, because the group is currently under revision. The parasites have been deposited in the Canadian National Collection (E.R.I. Lot. No. 70-389).

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CHEMICAL CONTROL OF THE JACK-PINE AND SPRUCE BUDWORMS WITH GROUND APPLICATION EQUIPMENT IN MANITOBA

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ABSTRACT

Nine insecticides were evaluated on pines *(Pinus* spp.) or spruce *(Picea* spp.) in recreation areas and forest plantations in Manitoba from 1967 to 1969 for control of the jack-pine budworm, *Choristoneura pinus pinus* Freeman, and spruce budworm, *C. fumiferana* (Clemens). Application equipment included knapsack-type compressed air sprayers and mist blowers, high-pressure hydraulic sprayers and a trailer-mounted mist blower. Results indicated that applications of Baygon(R), carbaryl, dimethoate, Dylox(R), fenitrothion, Matacil(R), phorate, or phosphamidon, reduced jack-pine budworm larval population levels and prevented serious feeding injury. Efficacy of malathion treatments was less conclusive. Applications of phosphamidon for control of the spruce budworm gave high larval mortality and prevented defoliation. The experimental applications showed also that ground equipment is practical where few and scattered low-acreage treatments are required.

INTRODUCTION

Forest trees in Canada have been treated with chemical insecticides for protection from insect defoliators for more than 40 years (Swaine 1928; Balch, Webb and Fettes, 1956). Generally, treatment has been restricted largely to aerial applications of DDT (1,1,1-trichloro-2,2-bis=(p-chlorophenyl) *ethane),* a compound now in disfavour because of its long residual activity and assimilation into ecological food chains. The history of DDT usage in Canadian forest practice is well documented (e.g., Macdonald 1968, Morris 1958, Webb 1959, 1960). Good levels of insect population control have been achieved, and applications have been inexpensive and simple. Alternative short-residue insecticides, on the other hand, are largely untested and may induce only erratic levels of control, may require special application techniques, and usually are several times more expensive than DDT. The forest manager and forest entomologist thus are involved in the development of a new era of practical applied insect control.

Very few insect defoliators currently cause injury of serious economic proportions in Manitoba and Saskatchewan. Only infestations of the jack-pine budworm[2] (DeBoo and Hildahl 1968), spruce budworm[3] (Ives, Brandt and Lawrence 1968), and the forest tent caterpillar[4] (Hildahl and Reeks 1960) have warranted consideration for applied control measures during recent years. Implementation of large-scale chemical control programs have not been undertaken, however, due to the inaccessibility and low economic value of most infested stands.

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2 *Choristoneura pinus pinus* Freeman (Lepidoptera: Tortricidae)

3 *C. fumiferana* (Clemens)

4 *Malacosoma disstria* Hubner (Lepidoptera: Lasiocampidae)

Intensive reforestation programs and increased usage of the forest for recreational purposes in the last decade have initiated reappraisals of certain forest land values. Protection of trees from serious injury and possible mortality due to insect attack now must be considered as an integral component of forest management. A previous paper (DeBoo and Hildahl 1967) reported on the results of experimental aerial applications of insecticides for control of jack-pine budworm infesting high-value stands in Manitoba. The present paper gives the results of companion testing with a variety of insecticides using ground application equipment in small forest plantation and recreation areas (i.e. campgrounds, picnic sites, roadsides) for control of jack-pine and spruce budworms. Major objectives were: (1) to test the efficacy of several insecticides as alternatives to DDT, (2) to evaluate the suitability of ground application equipment under Manitoba forest conditions, and (3) to achieve a desirable level of foliage protection (i.e. where minimal shoot mortality occurs). Mention of trade names and specific products is not intended as exclusive endorsement.

MATERIALS AND METHODS

Experimental applications of insecticides were made in June and July 1967, June 1968, and June 1969. With the exception of a series of applications for control of 3rd-instar larvae in 1968, all treatments were timed for control of the 4th instar, the period when larvae first feed openly and when foliage injury still is minimal. Chemicals selected for appraisal are listed in Table I. The following application equipment was used (code letters are those which appear in Tables III to VI):

A — KWH model 77 Knapsack mist blower
B — high-pressure hydraulic sprayers:
- (i) John Bean Spartan Model 33C, 15 gal (U.S.) capacity
- (ii) Westeel-Yoshii Y81-G special conversion, 200 gal (Fig. 1a)
- (iii) Westeel-EPM fire pumper, 500 gal (Fig. 1b)

C — Cyclone seed spreader, 10 lb capacity
D — Smith E-Z-S compressed air sprayer, 5 gal
E — John Bean Rotomist model 51, 75 gal (Fig. 1c)

All stands selected for treatment had either recently suffered severe defoliation or were expected to sustain heavy attack for the first time during the year of treatment (Table II). Estimates of both pre- and post-treatment larval abundance were determined by random branch sampling from mid-crown regions of trees in treated and untreated check plots. Foliage protection levels achieved then were expressed in terms of the % reduction of larvae per 300-360 linear inches of branch for pine (*Pinus banksiana* Lambert, *P. sylvestris* L.), and per 100 sq ft of foliage for spruce (*Picea glauca* (Moench) Voss, *P. mariana* (Miller) BSP) and by the % of foliage consumed (50% or more defoliation on new shoots after treatment was considered inadequate protection). As a comparison of efficacy of the insecticides was not intended, statistical interpretations (i.e., range tests) of the results were not made. The performance of each treatment was evaluated solely on the larval mortality/defoliation records taken.

RESULTS

The results of the experimental applications, expressed as five separate experiments over the three-year period, are found in Tables III to VI. With the exception of the malathion treatment (Table IV, where only 50% reduction in larval populations was achieved and defoliation resulted in 10% shoot mortality), all formulations and rates of application of insecticides tested provided effective foliage protection (not more than 25% defoliation, and insignificant shoot mortality). Although acceptable levels of defoliation are unknown (and will vary with tree species, age, vigor, etc.), preliminary studies have

Figure 1. Ground application equipment used in Manitoba:

a. 200 gal sprayer and farm tractor at Rocky Lake.

b. 500 gal sprayer and Bombardier J-5 at Red Rock Lake.

c. John Bean model 51 Rotomist and pick-up truck at Whiteshell Lake.

TABLE I

Organic Insecticides Tested 1967-69 (after Kenaga and Allison 1969)

Common Name[1]	Trade Name	Chemical designation	Source	Toxicity[2]
aminocarb	Matacil	4-dimethylamino-m-tolyl methylcarbamate	Chemagro Corp., Kansas City, Missouri	AO 30 AD 275 (<275)
arprocarb	Baygon	o-isopropoxyphenyl methylcarbamate	Chemagro Corp., Kansas City, Missouri	AO 95-175 AD> 1000
carbaryl	Sevin	1-naphthyl methylcarbamate	Union Carbide Canada Ltd., Toronto, Ontario; Stauffer Chemical Co., New York, New York	AO 307-986 AD>500- >4000
dimethoate	Cygon	0,0-dimethyl S-(N-methylcarbamoylmethyl) phosphorodithioate	Cyanamid of Canada Ltd., Rexdale, Ontario	AO 155-500 AD<150-1150
fenitrothion	Accothion	0,0-dimethyl 0- (4-nitro-m-tolyl) phosphorothioate	CIBA Co. Ltd., Dorval, Quebec; Cyanamid of Canada Ltd., Rexdale, Ontario	AO 250-670 AD 200->3000
malathion	Cythion	0,0-dimethyl phosphorodithioate of diethyl mercaptosuccinate	Cyanamid of Canada Ltd., Rexdale, Ontario	AO 885-2800 AD >4000
phorate	Thimet	0,0-diethyl-S-[(ethylthio)-methyl] phosphorodithioate	Cyanamid of Canada Ltd., Rexdale, Ontario	AO 1-5 AD 2-300
phosphamidon	Dimecron	2-chloro-N, N-diethyl-3-hydroxycrotonamide, dimethyl phosphate	CIBA Co. Ltd., Dorval, Quebec	AO 15-13 AD 125-150
trichlorfon	Dylox	dimethyl (2,2,2-trichloro-1-hydroxyethyl) phosphonate	Chemagro Corp., Kansas City, Missouri	AO 450-699 AD > 2800

1 Common names approved by the Entomological Society of America are given in italics.

2 AO = acute oral LD_{50} in mg/kg.; AD= acute dermal toxicity LD_{50} in mk/kg.

TABLE II.

Description of Stands Treated and Budworm Infestation Levels, 1967-69

Location	Stand type	Tree species	Height range (ft)	Trees/ acre	Acres treated	Pre-treatment budworm population level [1]	Attack rating [2]
1967 – Sandilands Provincial Forest							
1. Hadashville	Plantation	Scots pine	4-12	1,000	0.2	21	S
2. Marchand	Plantation	Jack pine	20-25	1,000	0.5	16	S
1968 – Whiteshell Provincial Park							
3. West Hawk L.	Natural	Jack pine	35-50	600	10.0	9	M
4. West Hawk L.	Natural	Jack pine	45-70	500	40.0	6	M
5. Brereton L.	Natural	Jack pine	25-70	300	20.0	27	S
6. Red Rock L.	Natural	Jack pine	35-65	400	2.0	7	M
7. Red Rock L.	Plantation	Jack pine	3-20	1,200	15.0	21	S
8. Meditation L.	Plantation	Jack pine	4-10	1,000	0.5	19	S
9. Meditation L.	Plantation	Jack pine	3-15	1,200	95.0	10	M
10. Meditation L.	Plantation	Jack pine	3-20	1,000	10.0	14	S
11. Meditation L.	Plantation	Jack pine	10-25	1,000	5.0	3	L
12. Betula L.	Natural	Jack pine	35-70	800	5.0	3	L
13. Whiteshell L.	Plantation	Jack pine	3-10	1,000	22.0	7	M
1969 – Rocky Lake Provincial Campground							
14. Wanless	Natural	White & black spruce	15-70	500	20.0	4	L

[1] Avg. number live larvae/15-18 in. branch sample; samples randomly selected from 10 to 30 trees 1-5 days before treatment.

[2] L - Light (no serious injury expected); M - Moderate (some crown thinning, a few top-killed trees and moderate radial increment reduction expected); S - Severe (some mortality, considerable top-killing and radial increment reduction expected).

TABLE III

Experimental Insecticide Applications for Control of 4th- and 5th- instar Jack-pine Budworm Larvae, 1967

	Treatment & formulation[1]	Rate of application[2]	Type of equipment[3]	No. trees treated	Avg. no. live budworm/300" branch sample[4] Pretreat. (-1 day)	Post-treat. (+3 days)	Population reduction (%)
				Experiment 1 (Hadashville), June 27			
I	trichlorfon (4 lb/gal EC)	2 gal	A	38	173	0	100
II	phosphamidon (90% EC)	1 gal	A	50	184	2	99
III	phosphamidon (90% EC)	2 qt	A	31	116	1	99
IV	phosphamidon (90% EC)	1 pt	A	50	207	7	97
V	phosphamidon/ fenitrothion (30% EC/20% EC)	1 gal	A	32	265	6	98
VI	phorate (10% G)	0.5 oz/in dbh*	C	32	163	5	96
VII	untreated check	—	—	50	210	184	9
				Experiment 2 (Marchand), July 4			
VIII	carbaryl (4 lb/gal Flow.)	4 gal	B	500	162	17	90
IX	untreated check	—	—	20	123	148	0

1 EC = emulsifiable concentrate; G - granular; Flow. = flowable (fine dispersion in water).

2 As mixed for 100 gal water, unless otherwise specified.

3 See text.

4 Two 15" branches from each of 10 randomly selected trees.

* Diameter breast height.

TABLE IV

Experimental Insecticide Applications for Early Control of 3rd-instar Jack-pine Budworm Larvae, 1968

	Treatment & formulation[1]	Rate of application[2]	Type of equipment[3]	No. trees treated[4]	Avg. no. live budworm/360" branch sample[5]		Population reduction (%)
					Pretreat. (-3 days)	Post-treat. (+30 days)	
	Experiment 3 (location 8, Table II, Meditation Lake), June 5						
I	aminocarb (80% WP)	2 lb	D	75	180	0	100
II	phosphamidon (90% EC)	2 qt	D	75	231	0	100
III	dimethoate (2 lb/gal EC)	2 qt	D	75	148	3	98
IV	trichlorfon (40% EC)	2 qt	D	75	120	2	98
V	phosphamidon/ fenitrothion (30% EC/20% EC)	1 gal	D	75	178	16	91
VI	malathion (57% EC)	1 qt	D	75	153	77	50
VII	untreated check	—	—	75	217	193	9

1 WP = wettable powder.

2 As mixed for 100 gal water.

3 See text.

4 3 replicates/treatment, 25 trees/replicate.

5 Two 18" branches from each of 10 randomly selected trees.

TABLE V

Experimental Insecticide Applications for Control of 4th-instar Jack-pine Budworm Larvae, 1968

	Treatment & formulation [1]	Rate of application[2]	Type of equipment[3]	Location (per Table II)	Avg. no. live budworm/360" branch sample[4]		Population reduction (%)
					Treatment	Untreated check	
	Experiment 4 (Whiteshell Provincial Park), June 20-24						
I	aminocarb (3 lb/gal ULV)	15 gal in 25 gal Panasol	E	13	0	43	100
II	phosphamidon (90% EC)	1 qt	B	12	0	18	100
III	phosphamidon (90% EC)	1 qt	B	11	2	43	95
IV	phosphamidon (90% EC)	1 qt	B	4	8	67	88
V	dimethoate (2 lb/gal EC)	2 qt	B	5	1	218	99
VI	dimethoate (2 lb/gal EC)	2 qt	B	6	5	82	94
VII	fenitrothion (80% EC)	1 qt	B	3	4	74	94
VIII	carbaryl (4 lb/gal Flow.)	1 qt	B	7	22	158	89
IX	arprocarb (17% EC)	1 gal	B	10	13	117	86
X	phosphamidon/ fenitrothion (90% EC/80% EC)	1 qt + 1 qt	B	9	9	43	85

1 ULV = ultra-low volume formulation.

2 As mixed for 100 gal water, unless otherwise specified.

3 See text.

4 Sampled 3-5 days after treatment, two 18" branches from each of 10 randomly selected trees.

TABLE VI

Experimental Insecticide Applications for Control of 4th-instar Spruce Budworm Larvae, 1969

Treatment & formulation		Rate of application[1]	Type of equipment[3]	Location (per Table II)	Avg. No. live larvae/100 sq.ft. foliage[2] Pre-treat. (-2 days)	Post-treat. (+3 days)	Post-treat. (+10 days)	Population reduction (%)
	Experiment 5 (Rocky Lake Provincial Campground), June 16							
I	phosphamidon (90% EC)	1 qt	B	14	239	115	34	86
II	untreated check [4]	—	—	14	239	196	189	21

1 As mixed for 100 gal water.

2 Avg. branch sample was 18 in. long x 14 in. wide (= 1.75 sq. ft. foliage).

3 See text.

4 No serious defoliation in treated plot; high % mortality in untreated check plot due to low temperatures.

indicated that trees may tolerate up to 50% defoliation of new shoots for one or two years without visible detrimental effect on growth. From 85 to 100% larval mortality levels were achieved. Treatments were most effective on trees 20 ft or less in height where optimum spray coverage was possible.

Of particular interest were the results obtained in Experiment 3 (Table IV) where excellent control was achieved with five of the six insecticides on 3rd-instar larvae. Many of the trees were severely defoliated (75%+) in untreated replications of the check plot, but hardly a needle was missing from treated trees.

The larger capacity equipment used (200 and 500 gal hydraulic sprayers, model 51 Rotomist) was well-suited for specific applications: the hydraulic sprayers delivered spray droplets to heights up to 60 ft; the mist blower covered approximately 15 rows of young plantation trees (6 x 6 ft spacing) with adequate spray deposit.

DISCUSSION AND CONCLUSIONS

Ground applications of selected insecticides for control of jack-pine and spruce budworms gave excellent protection of foliage and high levels of reduction in larval population density. Economical applications of short residue-low hazard insecticides from the ground are influenced, however, by the component cost factors (e.g., unit price of the competitive insecticides, availability of personnel and equipment, tree size, and density, etc.). The successful implementation of a stand protection program then is highly dependent upon the combination of the most economical factors as repetitive applications will be required during the insect attack years. Three examples are used to illustrate possible situations; infestations in (1) regional campgrounds, (2) young plantations on level sandy soil, (3) stands on rocky outcrops.

(1) **Regional campgrounds.** Where access roads are available and tall stands have been thinned for recreational use, hydraulic sprayers or mist blowers capable of reaching tree-tops are required. A conventional 1/2 ton pick-up truck or small farm tractor is necessary to haul these trailer-mounted sprayers (100-500 gal capacity). Stand density will influence the selection of equipment; if the stand is dense the hydraulic sprayer and 100 ft of high-pressure hose for interior movement will provide maximum penetration and coverage. A two-man crew, preferably permanent staff (e.g., parks or forestry personnel), is required for the operation and they should cover 30-60 acres/8-hr day.

(2) **Young plantations.** For evenly spaced trees 10 ft tall or shorter on level ground the same equipment may be suitable. The unit moves up and down between tree rows delivering optimum spray deposit between 60-100 ft horizontally. In machine-planted areas where large furrows are present, preliminary ground preparation may be necessary for access of the vehicle along pathways. Knapsack sprayers may be suitable when trees are small and inexpensive labour is available (e.g., from correctional institutions, rehabilitation camps).

(3) **Stands on rocky outcrops.** A tracked vehicle such as the Bombardier J-5 may be substituted for pick-up truck or farm tractor where land is uneven and rocky. Of necessity, travel will be slower, and a third crew member may be required to haul hose over rocks. Knapsack sprayers may be required to supplement or to substitute for applications in areas inaccessible by vehicle.

The purchase of expensive commercial spray equipment may be unnecessary for certain jobs. For example, a model 51 John Bean Rotomist with restricted vertical delivery and designed for mosquito abatement may be entirely suitable for applications in very young plantations. Simple modifications to plumbing systems of fire control water pumpers located throughout many forest and park regions can convert this stand-by equipment into "seasonal" hydraulic sprayers for local use.

The use of short residue insecticides in ground applications to small forested areas presents minimal hazard to wildlife, yet preserves both aesthetic and economic values attached to certain important stands. Protection requirements and allowable residue tolerances will govern the selection of insecticides, dosage rates, methods of application, and other factors influencing future forest insect control programs. The preservation of the tree, and not the eradication of the insect pest, must become the prime consideration for conservation of the environment in the interests of man.

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LITERATURE CITED

Balch, R.E., F.E. Webb and J.J. Fettes. 1955-56. The use of aircraft in forest insect control. For. Abstr. 16(4); 17(1)(2). (Reprinted as Forestry Abstracts Leading Article Series No. 23, 31 pp.).

DeBoo, R.F. and V. Hildahl. 1967. Aerial spraying for control of the jack-pine budworm in Manitoba. *Manitoba Ent.* 1: 21-26.

DeBoo, R.F. and V. Hildahl. 1968. Jack-pine budworm in central Canada. Can. Dept. For. and Rural Dev., Liaison and Services Note MS-L-4, 9 pp.

Hildahl, V. and W.A. Reeks. 1960. Outbreaks of the forest tent caterpillar, *Malacosoma disstria* Hbn., and their effects on stands of trembling aspen in Manitoba and Saskatchewan. *Can. Ent.* 92: 199-209.

Ives, W.G.H., N.R. Brandt and J.J. Lawrence. 1968. *In* Annual report of the forest insect and disease survey. For. Br., Can. Dept. Fish. and For., pp. 80, 94.

Kenaga, E.E. and W.E. Allison. 1969. Commercial and experimental organic insecticides. *Bul. Ent. Soc. Amer.* 15: 85-148.

Macdonald, D.R. 1968. Management of spruce budworm populations. *For. Chron.*, 44(3): 33-36.

Morris, R.F. *Ed.* 1958. The dynamics of epidemic spruce budworm populations. *Mem. Ent. Soc. Can.* 31, 332 pp.

Swaine, J.M. 1928. Forest entomology and its development in Canada. Can. Dept. Agric. Pamph. 97: 8-9.

Webb, F.E. 1959. Aerial chemical control of forest insects with reference to the Canadian situation. *Can. Fish Culturist* 24: 3-16.

Webb, F.E. 1960. Aerial forest spraying against spruce budworm — a problem of mutual interest in Canada and the United States. *J. Econ. Ent.* 53: 631-633.

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PREDATION OF MOSQUITO LARVAE BY THE FATHEAD MINNOW

Pimephales promelas RAF.[1]

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ABSTRACT

Pimephales promelas, the fathead minnow, is an important larvivorous fish and should be considered for mosquito control. Laboratory experiments show that the minnows are effective predators even in shallow water. At the latitude of Winnipeg (50°N) minnows were observed to overwinter in a permanent pool 1.2 m in depth.

There are many species of minnows native to Manitoba (Hinks 1943), but only a few are commonly found in lakes, streams and shallow pools. The fathead minnow *Pimephales promelas* Rafinesque, belongs to this ubiquitous group and is frequently encountered in permanently flooded roadside ditches around Winnipeg. It probably arrives in ditches each year via several indirect routes, but we also know that it can overwinter in relatively small ponds. Its northern range in North America extends to the tundra and its southern range to Mexico (McPhail and Lindsey 1970).

Surveys of mosquito developmental sites around Winnipeg showed that mosquito larvae were absent in pools where the fathead minnow occurred (Dixon 1969). A stock supply of the minnows (600) was maintained in our laboratory for nearly a year, in order to carry out experiments on predation of mosquito larvae. Spawning and egg laying by the minnows was not attempted during our study, but cultures can be maintained if desired (Mount 1968).

METHOD

Experiments were conducted in fifteen gallon glass aquaria fitted with thermostatically controlled heaters. The minnows were selected to be of a uniform size (6-8 cm in length) and their predator ability was tested at three different temperatures and at three different water depths. Increasing numbers of *Aedes aegypti* (L.) larvae were introduced into each tank until there were larvae surviving at the end of 24 hours. Once the maximum consumption level per minnow per day was determined, tests were begun using the same minnows. Each test was repeated for four days and the mean number of larvae consumed/minnow/day was determined. In the first experiment, only one minnow per tank was tested, but in subsequent experiments two minnows per tank were used.

RESULTS

Using one minnow per aquarium, the average consumption of instar IV larvae was 99/minnow/day (Table 1). Using two minnows per aquarium, the average consumption/minnow/day was 106. When instar III larvae were preyed upon, the average consumption increased to 143.

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At 25°C, the water level in the aquaria was varied while other factors remained constant. The minnows consumed 105 larvae/minnow/day in 6 cm of water, 134 in 12 cm and 160 in 27 cm (Table 1).

At 30°C, pupae were used as prey in the first experiment (Table 1). The minnows consumed 132 pupae/minnow/day. Tests were not conducted on instar IV larvae at 30°C, but comparing the performance of the predators at 25°C, we would anticipate that they would have consumed even more larvae than pupae at 30°C.

In the last test (Table 1), the minnow diet was supplemented with 0.5g of dried fish food per day (a surplus remained each day). This reduced the consumption of larvae to 77/minnow/day. The check experiment at 30°C was not included unfortunately, but again for the reason stated above, we would estimate that the consumption at 30°C would have been approximately double without dried fish food supplement.

TABLE 1

Predation of *Aedes aegypti* larvae by *Pimephales promelas* in the laboratory

Water Temp. °C	Mosquito instar or stage	Water depth cm	Avg consumption[1] /minnow/day
19[2]	4	12	99
19	4	12	106
19	3	12	143
25	4	6	105
25	4	12	134
25	4	27	160
30	pupa	12	132
30[3]	4	12	77

1 mean of 4 replicates.

2 one minnow/aquarium. The rest of the tests involved 2 minnows/aquarium.

3 diet was supplemented with 0.5g of fish food.

DISCUSSION

The laboratory experiments confirm field observations that the fathead minnow is larvivorous. They also show that the minnow will prey upon mosquito larvae in the presence of surplus dried fish food supplement. In the field the minnow could maintain itself on small crustacea, algae and detritus when mosquito larvae were absent.

The additive effect on predation, when two rather than one minnow was used, was of interest to us. This effect might be magnified even more by the presence of several minnows. This behavior might be due to competition for food or perhaps increased swimming activity bringing them in more frequent contact with prey.

Prey consumption increased with temperature. This would be a distinct advantage in the field, for in Manitoba our pest mosquitoes are most abundant during the warmest summer months. The observation that prey consumption increased with water depth, could also be an advantage in the field. Young larvae develop at the shallow edge of pools whereas older larvae and pupae disperse to deeper water. If small retaining pools (1-2m deep) were constructed in the center of a large temporary larval developmental site for *Aedes* mosquitoes, for example, the minnows would be able to survive all summer. We observed this phenomenon in several pools around Winnipeg, where natural depressions in mosquito developmental sites harbored the minnows throughout the summer. We also observed that with each heavy rain the minnows dispersed into the temporary pool margins, and receded to the confined area during dry periods. Mosquito larvae also moved to the deeper water as the pool dried, and provided prey for the fish.

In the field and the laboratory we observed that in shallow water the minnows remained under cover of protruding objects. When they left the security of their cover, they swam excitedly and devoured only a few larvae which were directly in their path. When the water was deeper, they did not seek cover and consequently spent more time feeding.

More instar III larvae than instar IV were consumed by the predators. The most likely explanation is that more larvae are required to make up a comparable biomass. No tests were made on the consumption of instar I or II larvae. They are larger than many crustaceans that serve as food for the fathead minnow and would undoubtedly be preyed upon.

During the winter of 1967-68, a continuous temperature record, using a remote reading recorder, was obtained from a fathead minnow pool near Winnipeg. The water in the pool was 1.2m deep in the fall. The bottom of the pool remained at $0^{o}C$ from the beginning of December to the end of April. The pool had an abundant population of minnows after the spring thaw.

If retaining pools 2m deep, as mentioned above, were constructed in the center of mosquito developmental sites, and these were nearly full of water in the fall, it is quite possible that the minnows would survive all year around. Annual stocking of these pools would not be necessary.

REFERENCES

Dixon, R.D. 1969. Ecology of mosquito larvae in the Winnipeg area and evaluation of insecticides for future use in mosquito control. M.Sc. Thesis. University of Manitoba. 191 pp.

Hinks, D. 1943. The fishes of Manitoba. Department of Mines and Natural Resources, Province of Manitoba.

McPhail, J.D. and C.C. Lindsey. 1970. Freshwater fishes of Northwestern Canada and Alaska. Bulletin 173. Fisheries Research Board of Canada.

Mount, D.I. 1968. Chronic toxicity of copper to fathead minnows *(Pimephales promelas,* Rafinesque). Water Research 2: 215-223.

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SOIL ACARINE FAUNA OF SOUTHEASTERN MANITOBA
II. RIPARIAN COMMUNITIES

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ABSTRACT

Fifty-six species of mites were identified from 5 river bank sites plus one adjacent forest site during 11 collecting dates at two sampling depths. The early winter temperatures attained minima of at least -18°C, however the populations generally increased in numbers during this period. Sites flooded by river water had the lowest populations.

INTRODUCTION

During the summer of 1968 litter and soil samples were collected from eighteen sites at monthly intervals in southeastern Manitoba for analysing the acarine fauna. Twelve of these sites were in forested areas either in organic terrain or in sandy soils overlain by a shallow litter layer and the acarine fauna has been reported (Oswald and Minty 1970). The remaining six sites constituted a transect from near the water line of the Whitemouth River up and over the river bank.

METHODS

The methods employed for obtaining the samples, extracting the mites, and analysing the fauna were previously reported in detail (Oswald and Minty 1970). Briefly, a volumetric sampler with a plastic central core having an area of 22 cm^2 and a length of 15 cm was used to obtain the samples. The core was cut transversely into two 7.5 cm lengths so that the sample could be split while remaining in the plastic cyclinder and inverted into funnels for extraction. Temperatures were obtained by placing a laboratory thermometer in the ground adjacent to the point of sampling at depths corresponding to the middle of the two subsamples. A battery of light bulbs was used to remove the mites which were collected in vials containing either picric acid or dilute ethanol. The mites thus obtained were counted by species under a dissecting scope.

DESCRIPTION OF SAMPLING SITES

Site 1 was located approximately 100 meters from the river bank. The other five sites were located in a transect from the crest of the river bank down to near the summer water line of the river. The river bank crest was 6 meters vertically above the river and the general slope of the bank was 45°. The sampling sites located on the river bank however, were situated on small irregular terraces that had smaller degrees of slope. The total distance of the bank from crest to toe was 12 meters. The description of each site is as follows:

Site 1: Located 100 m from the riverbank under *Thuja occidentalis* L., *Abies balsamea* (L.) Mill., and *Picea glauca* (Moench) Voss. The ground vegetation was composed of a discontinuous moss-lichen layer. The organic matter was 10 cm deep over sand on essentially level terrain. Standing water occurred on the site during the spring thaw.

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Site 2: Located on the river bank crest 6 m vertically and 14 m diagonally above the river level under *Populus tremuloides* Michx. and *Abies balsamea. Alnus rugosa* (Du Roi) Spreng. and *Cornus stolonifera* Michx. formed a discontinuous layer and (L.) Kuhn *Calamagrostis* spp., *Fragaria* sp., *Epilobium angustifolium* L., and *Pyrola* spp., formed a continuous layer. The organic matter was 8 to 9 cm deep over gravel.

Site 3: Similar to Site 2 but had a continuous shrub layer with few herbs.

Site 4: Located 4 m vertically and 8 m diagonally above the river on a 15^{o} west slope under *Picea glauca. Alnus rugosa* and *Aralia nudicaulis* L. were the main understory plants with some *Viburnum trilobum* Marsh, *Symphoricarpos occidentalis* Hook, *Cornus canadensis* L. and *Equisetum* spp. The organic matter was 7 to 8 cm deep over sand.

Site 5: Located 2.5 m vertically and 4 m diagonally above the river on a 20^{o} west slope under *Quercus macrocarpa* Michx, with some *Populus tremuloides* and *Fraxinus pennsylvanica* Marsh. var. *subintegerrima* (Vahl.) Fern. The understory vegetation consisted of grass and *Carex* with some *Alnus rugosa* and *Cornus stolonifera*. The organic matter was 7 to 8 cm deep over 8 cm of clayey sand overlying gleyed clay. The site was flooded by the river during spring of some years.

Site 6: Located under *Fraxinus pennsylvanica* var. *subintegerrima* on the first floodplain 2 m from the river and was inundated during periods of high water. The understory vegetation consisted of *Aralia nudicaulis*, *Actaea rubra* (Ait.) Willd., *Fragaria* sp., *Galium boreale* L., and *Equisetum* spp. The organic matter, 7 to 8 cm deep, was comprised mainly of recently fallen leaves and overlaid gleyed clay.

RESULTS

A total of 53 morphological forms were distinguishable under a dissecting scope with a 40 power magnification (Table I). The morphological forms usually represented a single species but in a few incidences they were comprised of two or more species either belonging to the same or different genera and are referred to as combinations. The cedar site (Site 1) had the highest number of species and the largest number of individuals while the floodplain site (Site 6) had the fewest species and individuals.

The Astigmata were represented by only one genus and were few in number in most sites, being absent in Site 4. The Prostigmata were most abundant in Site 3, mostly due to the large numbers of *Ledermuelleria rhodomela* and least in Site 6. Both the Mesostigmata and the Cryptostigmata were most abundant in Site 1 and least in Site 6.

The *Oppia minus — Oppiella nova* combination represented by far the most abundant species in all sites, however *Achipteria* sp., *Ceratozetes gracilis*, *Fuscozetes bidentatus*, *Peloribates* sp., *Phthiracarus sphaerulus*, *Rhysotritia ardua*, *Scheloribates* sp., and *Asca* were well represented in most, if not all sites. Other species including *Archoplophora laevis*, *Eremobelba flagellaris*, *Eupodes* sp., *Malaconothrus* sp., *Tectocepheus velatus*, *Ledermeulleria rhodomela*, *Dinychus* sp., *Pseudouropoda* sp., and *Trachytes* sp. were either restricted to one site or proportionately more abundant in a site type.

In most sites the populations attained maxima during autumn and minima during summer (Fig. 1), however Site 1 had a peak in the spring also and site 6 had no pronounced seasonal peak. The population maxima usually occurred when the temperature of the sample was near or below zero degrees centigrade.

DISCUSSION

The annual fluctuation in population size, with peaks in spring and early winter associated with low points during summer, has been commonly found in studies of soil acarine communities (Hairston and Byers 1954, Evans, Sheals and Macfarlane 1961, Dowdy 1965, Madge 1965a, Block 1966). The reason that population peaks were not observed during spring in the sites occurring on the river bank conceivably could be due to the

TABLE I.

Average number per square meter X 10^{-3} of each species extracted from each site on eleven collecting dates, "A" from the upper 7.5 cm and "B" from the lower 7.5 cm.

		Site					
Species		1	2	3	4	5	6
MESOSTIGMATA							
Amblyseius sp.	A	0.04	0	0.04	0.04	0	0
	B	0	0	0	0	0	0
Asca aphidioides Linneus	A	0.78	0.78	0.50	0.66	0.83	0.87
and *A. garmani* Hurlbutt	B	0.04	0.29	0.54	0.41	0.21	0.17
Cheiroseius cassiteridum	A	0.04	0.08	0.12	0.04	0	0
Evans & Hyatt	B	0	0	0	0	0	0
Dinychus sp.	A	1.08	0	0	0	0	0
	B	0.04	0	0	0	0	0
Gamasellus vibrissatus	A	0.95	0.29	1.16	0.41	1.65	0.45
Emberson	B	0	0.21	0	0.21	0.25	0
Hypoaspis nolli Karg	A	0.45	0.04	0.04	0.08	0.04	0.08
	B	0	0.04	0.04	0.08	0	0.04
Ololaelaps venetus	A	0.08	0	0.08	0	0.08	0
Berlese	B	0	0	0	0	0.12	0
Parazercon radiatus	A	1.86	0.83	0.58	1.12	0	0.08
Berlese	B	0.08	0.74	0.17	0	0	0
Pseudouropoda sp.	A	0	0	0	0.95	0	0
	B	0	0	0	0	0	0
Trachytes sp. near	A	0.41	0	0	0	0	0
pyriformis Kramer	B	0.04	0	0	0	0	0
Veigaia mitis Berlese	A	0.08	0.04	0	0.04	0.29	0.33
	B	0	0.04	0	0.12	0.04	0.12
Zercon alaskensis	A	0	0.04	0.04	0.04	0	0
Sellnick	B	0	0	0	0	0	0
Total Mesostigmata	A	5.77	2.10	2.56	3.38	2.89	1.81
	B	0.20	1.32	0.75	0.82	0.62	0.33
PROSTIGMATA							
Bdella muscorum Ewing and	A	0.08	0	0.04	0	0.08	0.04
Spinibdella ornata Alyea	B	0	0	0	0	0	0
Cunaxa setirostris	A	0.25	0.17	0	0.21	0.17	0.08
Hermann	B	0	0	0	0	0	0
Eupodes sp.	A	0	0	0.33	0.41	0	0
	B	0	0	0	0.08	0	0

Table I., (continued)

Species		Site 1	2	3	4	5	6
Ledermuelleria	A	0.50	0	2.52	0.04	0	0
rhodomela Koch	B	0	0	0.12	0.04	0	0
Microtrombidium sp.	A	0.45	0.45	0.08	0.21	0.04	0.04
near *parvum* Oudemans	B	0	0.04	0	0.17	0.04	0.04
Pachygnathus sp.	A	0.29	0.04	0	0.25	0.17	0.08
	B	0.08	0.12	0	0.04	0.08	0
Pseudopygmephorus sp.	A	0.17	0.25	0.17	0.12	0.45	0.12
	B	0.04	0.04	0.62	0.04	0.08	0
Rhagidia sp.	A	0.21	0.41	0.17	0.53	0.25	0.12
	B	0	0.08	0	0.33	0.29	0
Stigmaeus scaber	A	0.08	0	0.04	0.04	0	0
Summers	B	0	0	0	0	0	0
Total Prostigmata	A	2.03	1.32	3.35	1.81	1.81	0.48
	B	0.12	0.28	0.74	0.70	0.49	0.04
ASTIGMATA							
Rhizoglyphus sp.	A	0.12	0.24	0.04	0	0.17	0.04
	B	0.08	0.08	0	0	0.12	0.04
CRYPTOSTIGMATA							
Achipteria sp. near	A	3.47	0.74	2.19	1.26	0.04	0.12
nitens Nicolet	B	0.25	0.12	0.17	0.25	0	0
Archoplophora laevis	A	4.30	0.45	0	0	0.29	0
Jacot	B	0.99	0.08	0	0	0.21	0
Carabodes sp.	A	0.12	0.04	0.33	0	0	0
	B	0	0	0	0	0	0
Cepheus sp. near	A	0.04	0	0.29	0.08	0.04	0
corae Jacot	B	0	0.04	0	0	0	0
Ceratoppia bipilis	A	0	0.62	0.41	0.08	1.49	0.12
Hermann	B	0.04	0.29	0.04	0.04	0.04	0
Ceratozetes gracilis	A	1.28	0.41	0.91	0.45	0.41	0.58
Michael	B	0.25	0	0	0.29	0.21	0.33
Ceratozetes thienemanni	A	0.12	0.21	0.29	0.17	0.78	0.04
Willman	B	0	0.08	0	0.29	0.70	0.08
Eobrachychthonius	A	1.65	0.62	0.12	0.12	0.25	0
latior Berlese	B	0.04	0.87	0.12	0.37	0.17	0
Epidamaeus sp.	A	0	0.08	0	0	0	0.12
	B	0	0.04	0	0	0	0
Eremobelba flagellaris	A	0	2.15	0	0.62	0.70	0.08
Jacot	B	0	0.37	0.04	0.12	0.12	0

Table I., (continued)

Species		Site 1	2	3	4	5	6
Eulohmannia ribagai Berlese	A	0.08	0.04	0	0.04	0.08	0
	B	0	0	0	0.29	0.04	0.04
Eupelops sp.	A	0.04	0	0	0.08	0	0
	B	0	0	0	0	0	0
Fuscozetes bidentatus Banks	A	1.36	0.17	0.41	0.62	0.91	0.12
	B	0.25	0	0.04	0.08	0.21	0
Gustavia sp.	A	0.54	0.38	0	0.12	0.54	0.08
	B	0.04	0.08	0	0	0.41	0
Gymnodamaeus sp. near *bicostatus* Koch	A	0.04	0.41	0.04	0.78	0	0.04
	B	0	0.08	0	0.08	0	0.04
Hoplophthiracarus pavidus Berlese	A	0.62	0.21	0.17	0.08	0.25	0.12
	B	0.78	0.08	0.04	0.04	0	0.04
Hypochthoniella minutissmus Berlese	A	1.90	0.66	0.21	0.21	0	0
	B	0.21	0.21	0	0.17	0.04	0.04
Lucoppia sp.	A	0	0	0	0.08	0.04	0
	B	0	0	0	0	0	0
Malaconothrus sp.	A	1.44	0	0	0.08	0.04	0
	B	0.25	0.17	0	0	0	0
Nanhermannia sp.	A	0.33	0.29	0	0.50	0	0.08
	B	0	0.17	0	0.08	0	0
Oppia minus Paoli and *Oppiella nova* Oudemans	A	18.68	21.07	11.74	6.86	3.39	1.94
	B	3.47	13.02	6.28	5.41	2.85	1.28
Peloribates sp.	A	0.54	1.99	1.24	1.12	2.11	0.33
	B	0	0.83	0.04	0.58	0.25	0.08
Pergalumna sp.	A	0.29	0.17	0.25	0	0	0.21
	B	0	0.04	0	0.04	0	0
Phthiracarus sphaerulus Banks	A	4.42	0.74	1.82	0.91	1.94	0.87
	B	0.74	0.12	0.29	0.33	0.17	0.37
Propelops sp. near *pinicus* Jacot	A	1.32	0.12	0.25	0.50	0	0
	B	0.17	0.08	0	0.17	0.04	0.04
Rhysotritia ardua Koch	A	1.28	0.41	0.45	0.17	0.99	0.37
	B	0.33	0	0	0.12	0.12	0
Scheloribates sp. near *pallidulus* Koch	A	0.33	0.62	0.17	0.37	3.55	0.12
	B	0.04	0.17	0	0.21	3.35	0.08
Steganacarus diaphanum Jacot	A	0.41	0.08	0	0.17	0.08	0.08
	B	0	0.04	0	0	0.04	0
Tectocepheus velatus Michael	A	4.17	0.08	0.04	0.08	0	0
	B	0.17	0.04	0	0	0	0
Tryhypochthonius tectorum Berlese	A	0.04	0.08	0	0.04	0.04	0.04
	B	0	0.12	0	0	0	0
Xenillus sp.	A	0	0.29	0.12	0.08	1.03	0.08
	B	0	0	0	0.04	0.12	0.04
Cryptostigmatid nymphs	A	0.66	0.33	0.29	1.61	1.03	0.08
	B	0.21	0.04	0	0.24	0.12	0
Total Cryptostigmata	A	49.47	33.46	21.74	17.38	20.02	5.62
	B	8.89	17.18	7.06	9.24	9.21	2.83
Total Acarina	A	57.39	37.12	27.69	22.57	24.90	7.95
	B	9.29	18.86	8.55	10.76	10.44	3.24

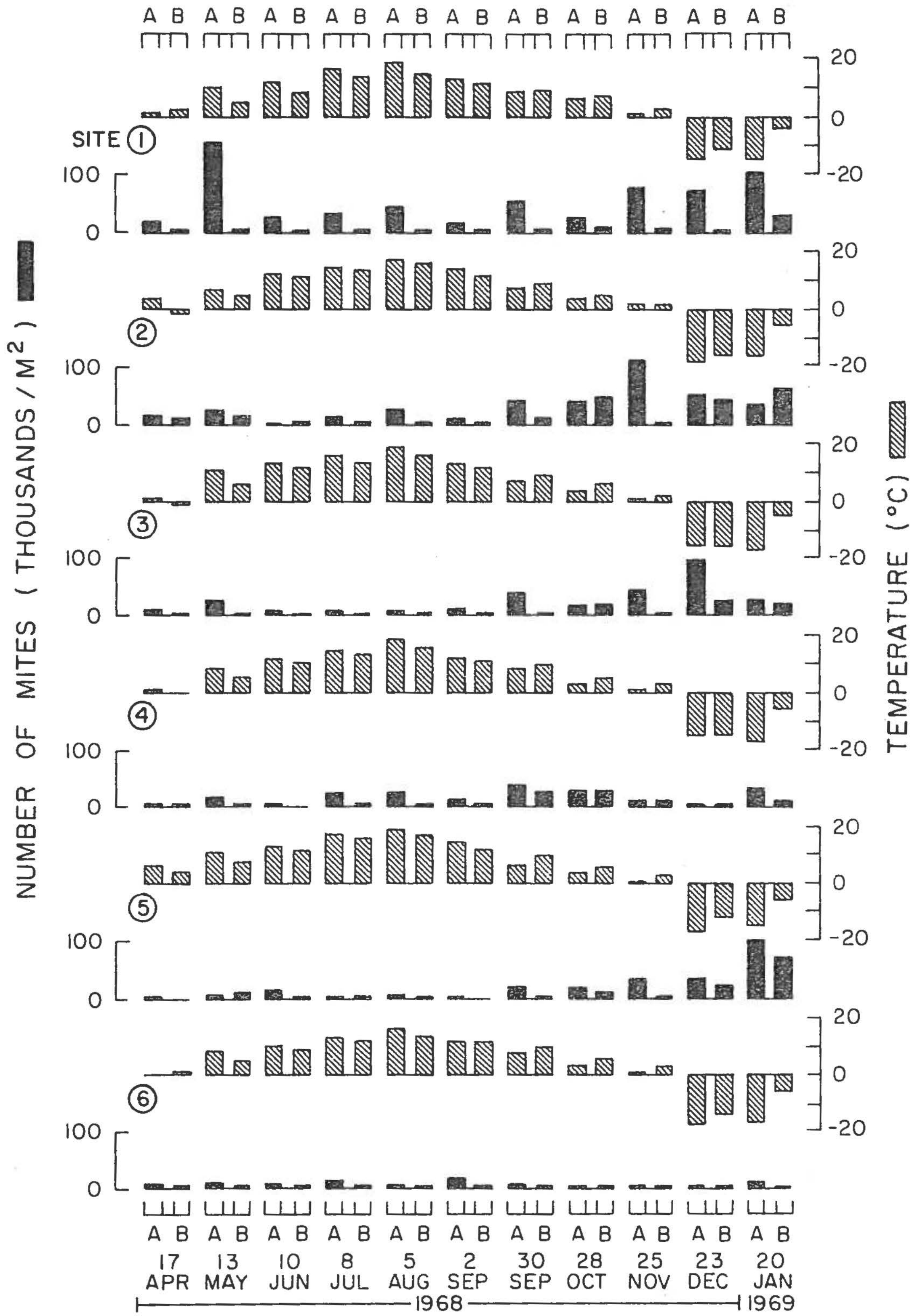

Figure 1. Acarine community densities and temperatures of surface (A) and subsurface (B) samples from each site on 11 collecting dates.

removal of the mites by rapidly moving water during snow melt and spring rains. Water runs down the bank from upland areas as evidenced by erosion patterns. Site 6, occurring adjacent to the river, supports the possibility of mites being removed by running water since it showed no seasonal peaks. Fall rains are common in the watershed and the river level fluctuates in accordance with the amount and intensity of rain often flooding the lower levels of the river bank.

The moving water not only removes the mites but washes some of the organic and loose mineral matter away as well, leaving mostly the coarser material that is held by the vegetation. This was most pronounced in Site 6 which essentially had nothing but recently fallen litter remaining over gleyed clay. The gleyed clay does not provide a favorable habitat for mites because of its compactness and high plasticity. The combination of these factors probably accounts for the small populations occurring in Site 6. In contrast, Site 1 was flooded by standing or slow moving water in spring but had well decomposed organic matter mixed with litter, and had the largest and most diverse community of mites.

The low temperatures (down to -18°C) attained during December and January are below the cold death point of soil mites found by Madge (1965b). The mites used by Madge to determine the cold death point, however, were not acclimatized which probably accounts for their lack of tolerance to colder temperatures. The species indicating population increases during this time included *Gamasellus vibrissatus*, *Hypoaspis nolli*, *Trachytes* sp., *Parazercon radiatus*, *Ledermuelleria rhodemela*, *Achipteria* sp., *Archoplophora laevis*, *Ceratoppia bipilis*, *Oppia minus-Oppiella nova*, *Peloribates* sp., *Phthiracarus sphaerulus*, *Scheloribates* sp., and *Xenillus* sp. Although collections were not possible from February to April, it is doubtful if the soil temperature went much below that recorded in December and January because of the insulation provided by the accumulated snow. The night time temperatures during the collecting period, however, conceivably could have been below -18°C at least in the upper layer. Mites have been found in most arctic and boreal environments where the soil is frozen during part of the year (Hammer 1952, 1955, 1967, Dowdy 1965, Reeves 1965, Krivolutsky 1967, Wallwork 1967.).

In comparison to the forested sites examined previously (Oswald and Minty 1970) the acarine populations associated with the river bank communities were generally smaller than those associated with the forest site types, although they approached the densities of the cut-over jack pine site. The river bank sites were open and exposed to both wind and insolation as was the cut-over site. The drying effect of the wind and sun probably accounts for the smaller populations in these sites since soil mite populations generally are adversely influenced by low humidity and high temperatures (Hairston and Byers 1954, Madge 1964, Reeves 1965).

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The authors are indebted to Drs. E.E. Lindquist, Canada Department of Agriculture and V.G. Marshall, Canadian Forestry Service for identification of the mites. Dr. Marshall reviewed the paper and offered many helpful suggestions. Mr. Frank Dendwick's assistance with the collections is appreciated.

LITERATURE CITED

Block, W. 1966. Seasonal fluctuations and distribution of mite populations in moorland soils, with a note on biomass. J. Anim. Ecol. 35: 487-504.

Dowdy, W.W. 1965. Studies on the ecology of mites and collembola. Amer. Midl. Natur. 74: 196-210.

Evans, G.O., J.G. Sheals, and D. Macfarlane. 1961. The terrestrial acari of the British Isles. Vol. 1. Academic Press, London.

Hairston, N.G. and G.W. Byers. 1954. The soil arthropods of a field in southern Michigan; a study in community ecology. Contrib. Lab. of Vert. Biol. 64. Univ. of Michigan.

Hammer, M. 1952. Investigations on the microfauna of northern Canada. Part I. Oribatidae. Acta Arct. 4: 1-108.

Hammer, M. 1955. Alaskan oribatids. Acta Arct. 7: 1-36.

Hammer, M. 1967. Some oribatids from Kodiak Island near Alaska. Acta Arct. 14: 1-25.

Krivolutsky, D.A. 1967. Some observations on the quantitative distribution of oribatid mites in the zonal soil types of the U.S.S.R. p. 39-41. *In* Evans, G.O. (ed.) Proc. 2nd Intern. Cong. Acarology, England.

Madge, D.S. 1964. The humidity reactions of oribatid mites. Acrologia 6: 566-591.

Madge, D.S. 1965a. A study of the arthropod fauna of four contrasting environments. Pedobiologia 5: 289-303.

Madge, D.S. 1965b. The effect of lethal temperatures on oribatid mites. Acarologia 7: 121-130.

Oswald, E.T. and L.W. Minty. 1970. Soil acarine fauna of southeastern Manitoba. I. Forested communities. Manitoba Entomol. 4: 76-87.

Reeves, R.M. 1965. Synecology of forest soil oribatei and related soil microarthropods. Ph. D. Thesis, Syracuse University.

Wallwork, J.A. 1967. The zoogeography of antarctic cryptostigmata. p. 17-20. *In* Evans, G.E. (ed.) Proc. 2nd Intern. Cong. Acarology, England.

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POPULATION TRENDS OF APHIDS ON CEREAL CROPS IN MANITOBA, 1968-1969

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ABSTRACT

Population trends of English grain aphid and corn leaf aphid on wheat, oats and barley, and of rose grass aphid on barley, were studied in fields in 1968 and 1969. Studies included the effects of weather, predators, parasites, fungus disease, emigration and immigration on individual colonies on plants.

INTRODUCTION

The most commonly found species of aphids on wheat, oats or barley in Manitoba are the English grain aphid, *Macrosiphum (Sitobion) avenae* (Fabricius); the rose grass aphid, *Metopolophium dirhodum* (Walker); the oat bird-cherry aphid, *Rhopalosiphum padi* (Linnaeus); the corn leaf aphid, *Rhopalosiphum maidis* (Fitch); and the greenbug, *Schizaphis graminum* (Rondani). They may be found on cereal crops during July and August of each year, but only rarely in sufficient numbers to require the application of insecticides for control.

The factors which affect the population numbers of aphids in the field in Manitoba have not been studied. When a grower notices aphids on his crop, and asks for advice on control, we are unable to advise him with accurate information on possible damage, either from aphid feeding or from the aphid-transmitted barley yellow dwarf virus. Damage to plants under controlled conditions in a plant growth cabinet has been documented (Apablaza and Robinson 1967), but field studies are necessary to extend our knowledge to conditions where the effects of weather, predators, parasites and diseases are not excluded.

Aphid populations have been sampled by many different methods; by various kinds of traps, by sweeping, by counts of numbers of plants infested, or by counting numbers of individuals on plants. These methods of sampling may indicate what is happening in the field as a whole, but studies must be made to record the progress of individual colonies in the field to determine the reasons for population fluctuations. The following is a brief summary from field studies on individual colonies reported by Malyk (1971).

METHODS

The studies were made in 1968 or 1969 on natural populations of aphids in fields at Glenlea Research Station, 12 miles south of Winnipeg. One hundred plants, each with an aphid colony of one species, were chosen from one field. Records were made at approximately 5 day intervals on increase or decrease in colony size, losses due to parasites or disease, and changes due to emigration or immigration by alate adults. Presence of predators in a colony was noted, but total loss of a colony could be caused by predators or by heavy winds or rain, and it was not always possible to clearly determine the reason. The stage of plant growth and position of colonies on the plants were also recorded.

If no aphids were found on one of the sample plants, another plant in the field, with aphids, was chosen to replace it for further sampling observations, thus keeping the total always at 100 plants. The data from those observations are recorded by Malyk (1971). Calculations from these data are shown pictorially in Figs. 1-7. One hundred plants represented an unknown proportion of all the plants in the field (100 P). "Trend in proportion of plants infested" was calculated for each sampling date as a per cent of the originally infested plants still infested at that sampling date. "Number of live aphids on 100 plants" represents numbers present on 100 plants at the beginning of each sampling interval. "Calculated population trend" is a product of the number of live aphids on 100 plants by the proportion of plants infested.

Data were obtained either in 1968 or 1969 for English grain aphid on wheat, oats and barley, corn leaf aphid on wheat, oats and barley, and rose grass aphid on barley.

RESULTS

English grain aphid on Manitou wheat, 1969 (Figure 1)

"Trend in proportion of plants infested" decreased steadily throughout the sampling period, due to the combined effects of wind, rain, and predators. Losses associated with parasites, fungus disease or emigration were low throughout the season. "Calculated population trend" shows that the numbers of aphids in the field increased from July 8 to July 20, and then decreased as combined effects of the adverse environmental factors overcame the rapid natural increase in aphid numbers associated with their parthenogenetic and ovoviviparous reproduction. The large loss shown for July 30 was believed to result from a heavy rain (1.92 inches) between sampling dates.

English grain aphid on Harmon oats, 1968 (Figure 2)

"Trend in proportion of plants infested" decreased throughout the sampling period; the effects of a heavy rain (1.51 inches) and wind (56 mph) are evident for the period July 15-18. Although number of live aphids on infested plants increased during the sampling period, "calculated population trend" remained fairly low and constant. Between August 1 and 9 heavy rains totalling 3.45 inches caused losses in both total numbers and colonies so that the sampling was terminated. Counts of predators were low in this field, and losses due to parasites or fungus disease were low until the counts of August 9, when they were 15.7 and 12.6 per cent respectively.

English grain aphid on Conquest barley, 1968 (Figure 3)

"Trend in proportion of plants infested" decreased throughout the sampling period and was associated with rain, predators, parasitism, disease and emigration. "Calculated population trend" reached a peak on August 14 and then slowly declined. The per cent parasitized and per cent diseased were 6.2 — 12.4 and 3.3 — 9.7 respectively for the period August 14-31.

Corn leaf aphid on Manitou wheat, 1969 (Figure 4)

"Trend in proportion of plants infested" decreased throughout the sampling period and was associated with the effects of wind or rain or predators. No losses were recorded as due to the effects of parasites, fungus disease or emigration. "Numbers of live aphids on the plants", and "calculated population trend" increased to August 22, and then declined, due mainly to predators which were abundant in this field.

Corn leaf aphid on Harmon oats, 1969 (Figure 5)

"Trend in proportion of plants infested" decreased throughout the sampling period. The total numbers of aphids in the field began to decline after September 1, and "calculated population trend" decreased throughout the season. Predators were present in fairly high numbers in this field, but no losses due to parasites, fungus disease, or emigration were recorded.

Corn leaf aphid on Conquest barley, 1969 (Figure 6)

Corn leaf aphids were more abundant on barley than on wheat or oats, and often reproduced to very large numbers on barley. On July 25, 14375 aphids were present on 100 plants. Large numbers of alates usually formed on plants crowded with aphids. Numbers of aphids on plants began to decline rapidly after July 25, due in part to the dispersal of winged aphids. In addition there was a heavy rain (1.92 inches) with high winds between July 25 and July 28; also, large numbers of predators were found on the plants between July 25 and August 9.

The flat line (Figure 6) for "trend in proportion of plants infested" shows one serious flaw in the method of representing this trend, because it does not show increases in the proportion of plants infested, though there obviously were increases in this field of barley in 1969 which was heavily infested.

Rose grass aphid on Conquest barley, 1968 (Figure 7)

"Trend in proportion of plants infested" decreased throughout the sampling period. On August 20, 1303 aphids were present in 100 colonies, but the "calculated trend" slowly declined after August 6. Losses associated with parasites occurred throughout the season and ranged from 3.6 — 7.9 per cent. Losses due to fungus disease were recorded throughout the season, and varied from 4.4 to 23.0 per cent. Predators and rain also caused some losses, but large numbers of aphids were still on the plants when they were harvested.

DISCUSSION

Figures 1-7 show that initial aphid populations vary according to aphid species, plant species, stage of plant growth and preference of the aphid for the host plant. Fluctuations in aphid numbers during the growing season of the crop vary from year to year, depending on unfavorable factors in the environment. Figures 1-5 apparently show the normal population trends. Large numbers of colonies were found in the fields prior to plant heading. Many of these colonies were completely destroyed, by wind and rain and predators, so that the proportion of plants infested gradually declined as the season progressed. Aphid reproduction increased rapidly in those colonies which were not destroyed, so that total number of aphids in the field increased for 2-3 weeks, and then decreased. Catastrophic aphid losses occurred at any time when there were heavy rains and strong winds to knock the aphids from the plants. Figures 6 and 7 show examples of heavier than normal populations of aphids. If these populations occurred on very young plants, the plants may be killed by the aphids unless they are sprayed with insecticides. If the populations do not become heavy until the plants are nearly mature, numbers of aphids decline as the plants ripen. It should be possible, with further studies, to determine an economic injury threshold based on aphid species, plant species, stage of plant growth, and numbers of aphids present on the plants.

ACKNOWLEDGEMENTS

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REFERENCES

Apablaza, J.U., and A.G. Robinson. 1967. Effect of three species of aphids on barley, wheat or oats at various stages of plant growth. Can. J. Plant Sci. 47: 367-373.

Malyk, M.R. 1971. Factors affecting the numbers of aphids on grain crops in Manitoba with observations on aphid predators and parasites. M.Sc. Thesis, University of Manitoba, Winnipeg.

Received 30 June, 1971.

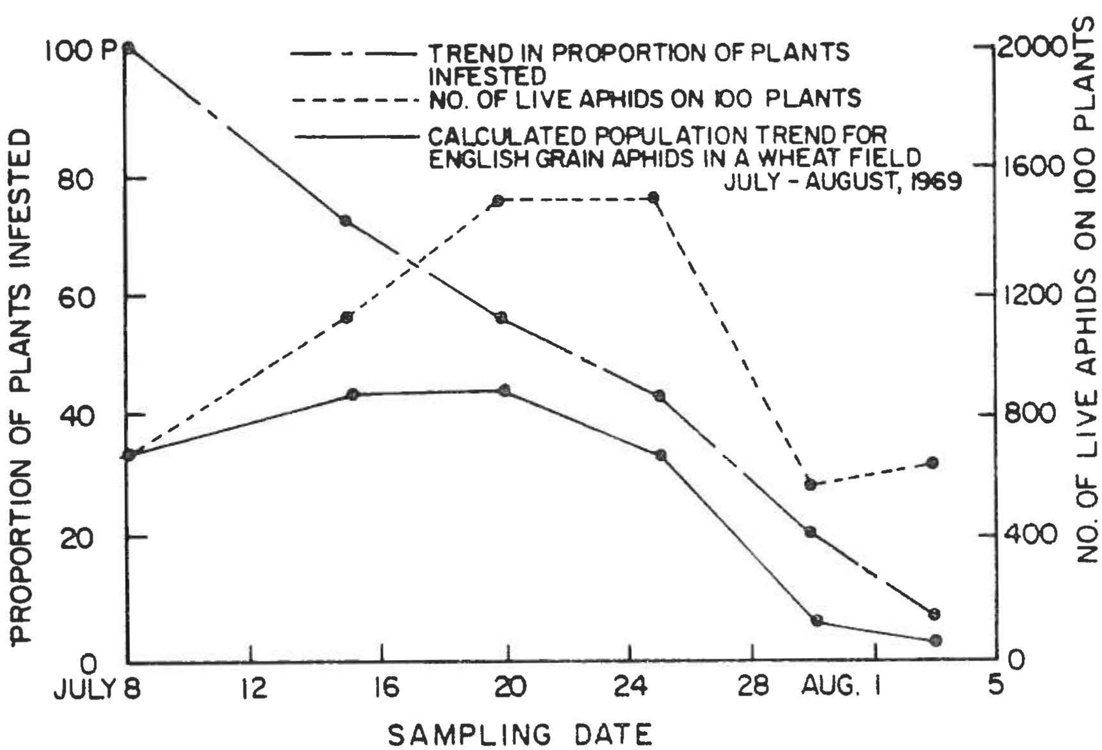

FIGURE 1. Population trend for English grain aphids in a wheat field July - August, 1969.

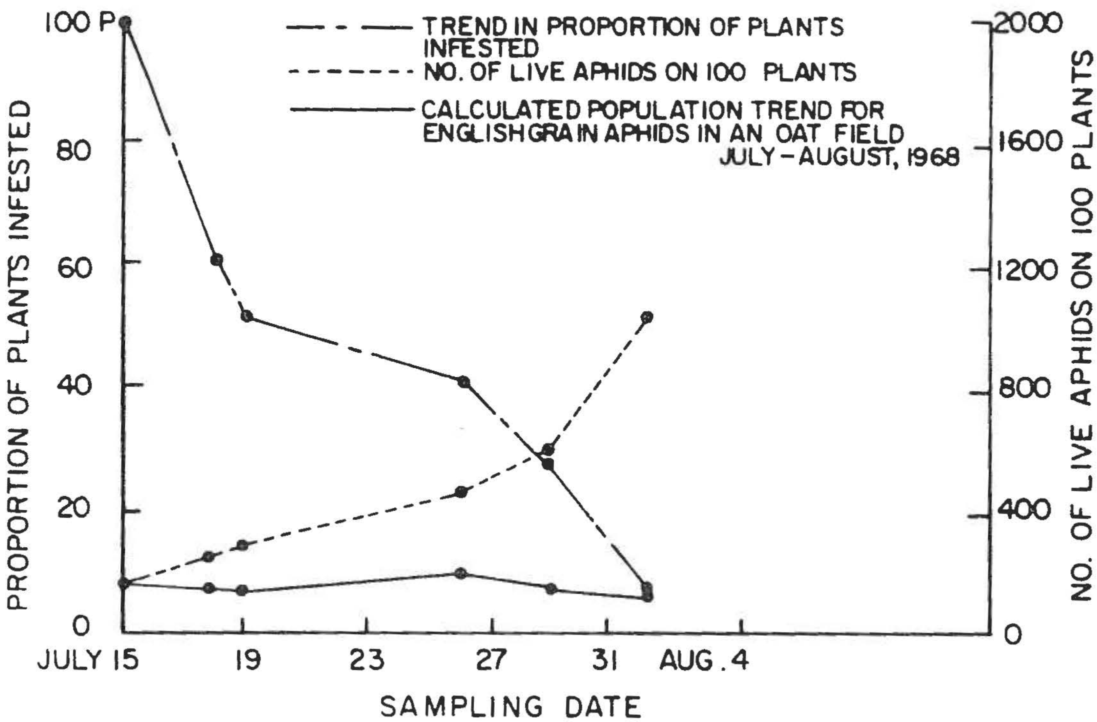

FIGURE 2. Population trend for English grain aphids in an oat field July – August, 1968.

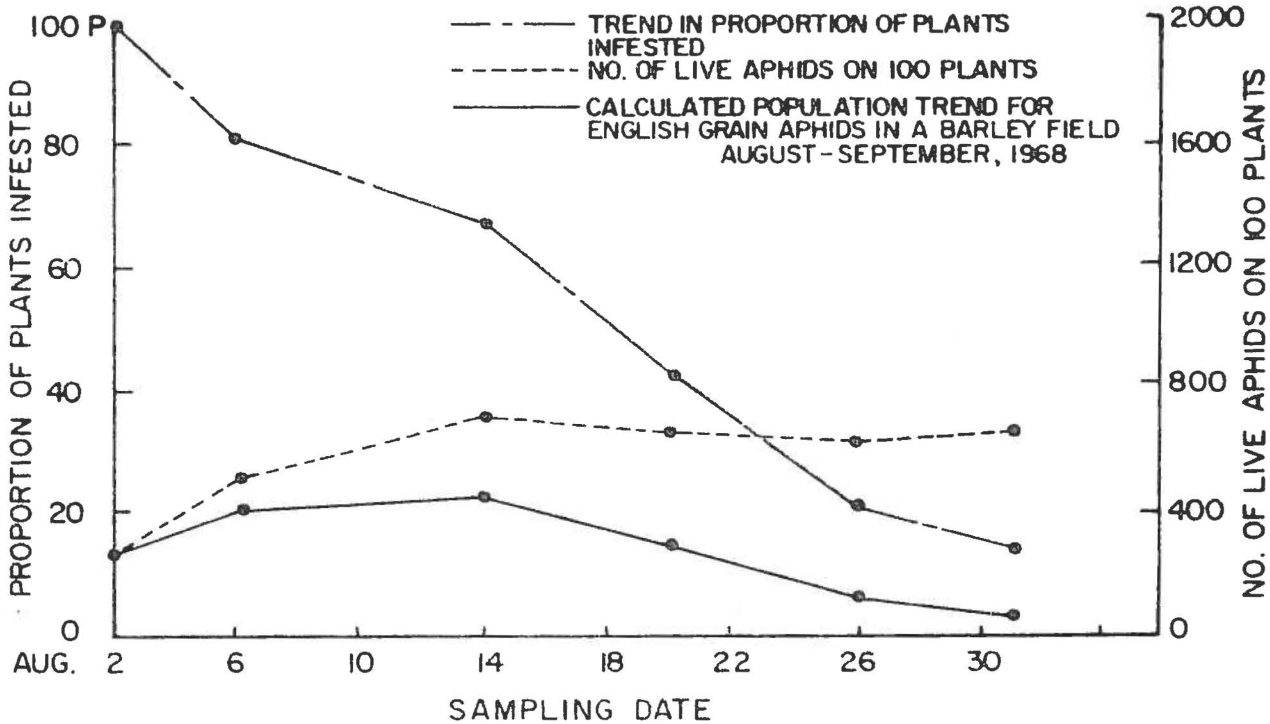

FIGURE 3. Population trend for English grain aphids in a barley field August – September, 1968.

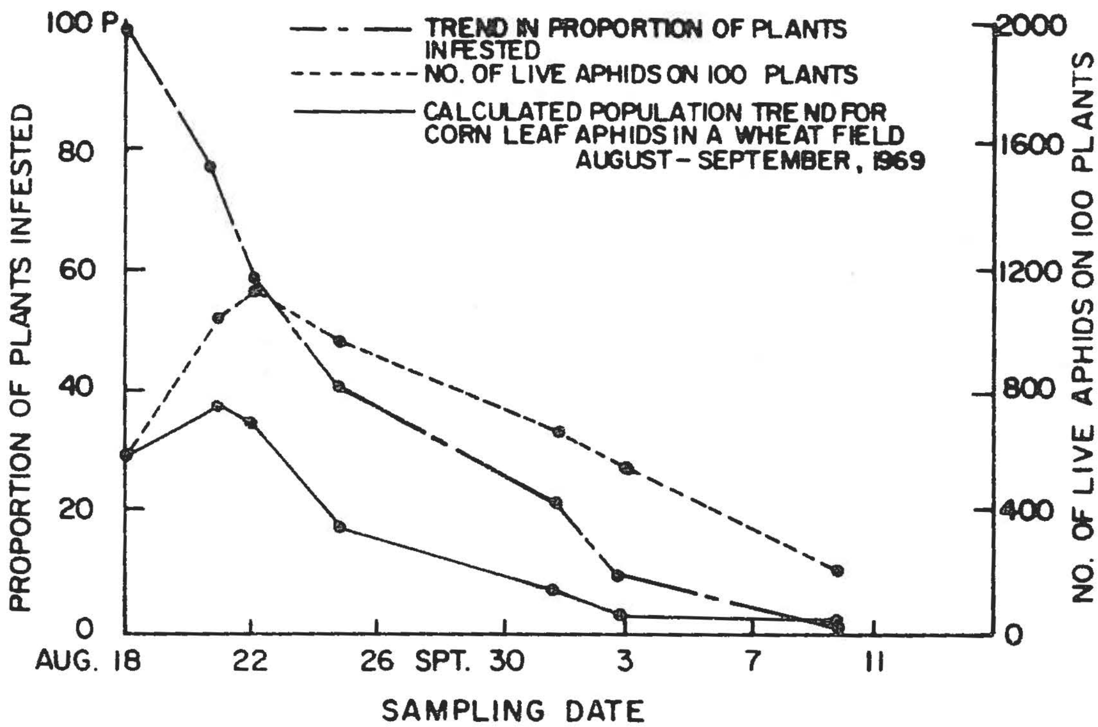

FIGURE 4. Population trend for corn leaf aphids in a wheat field August-September, 1969.

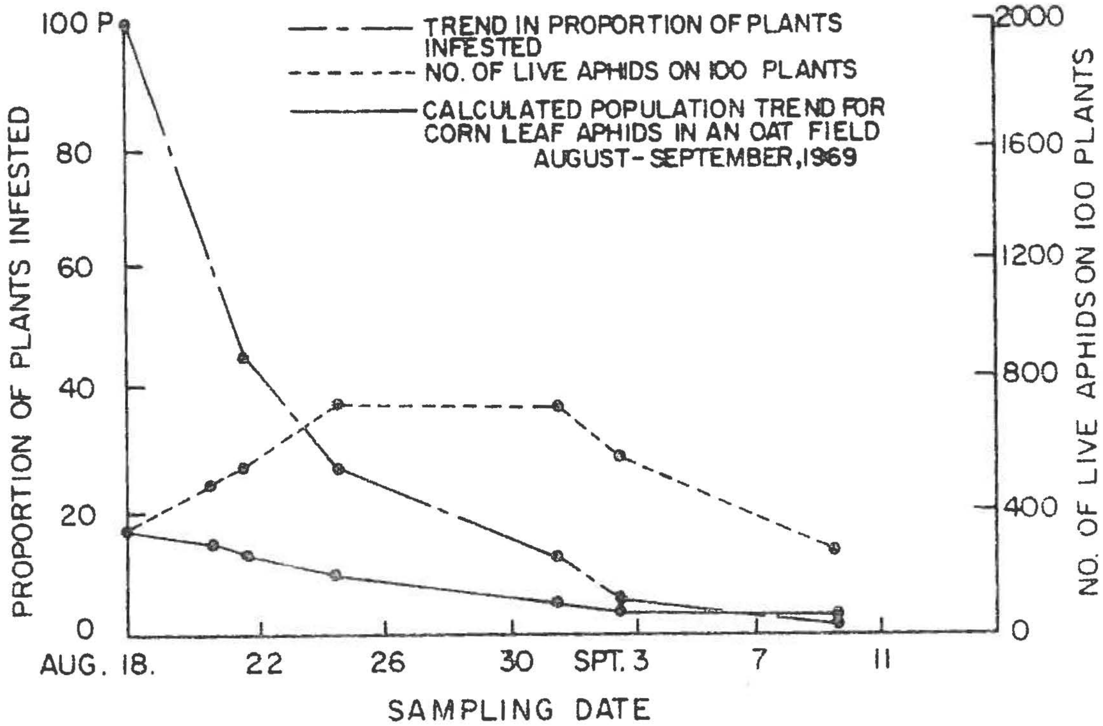

FIGURE 5. Population trend for corn leaf aphids in an oat field August - September, 1969.

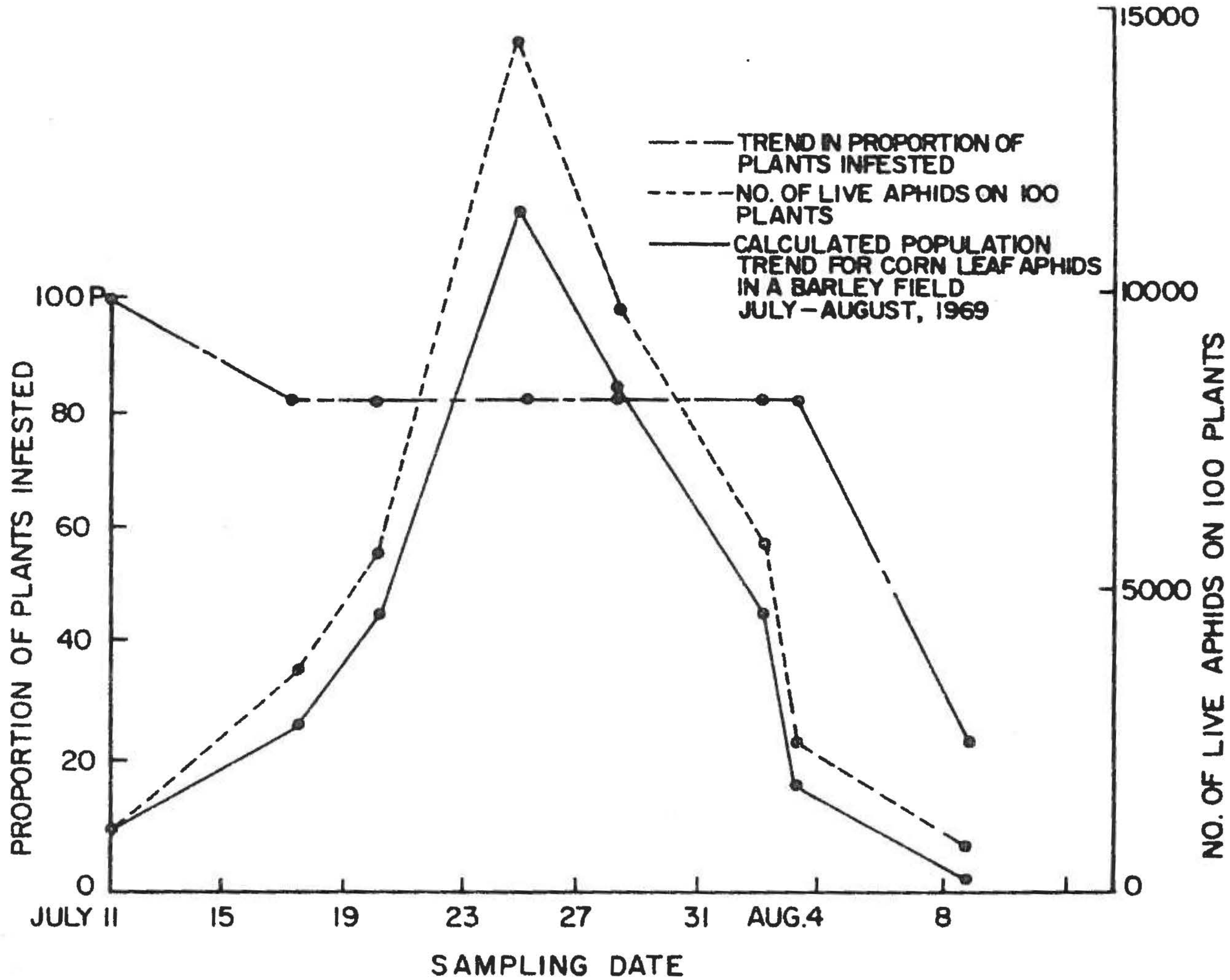

FIGURE 6. Population trend for corn leaf aphids in a barley field July – August 1969.

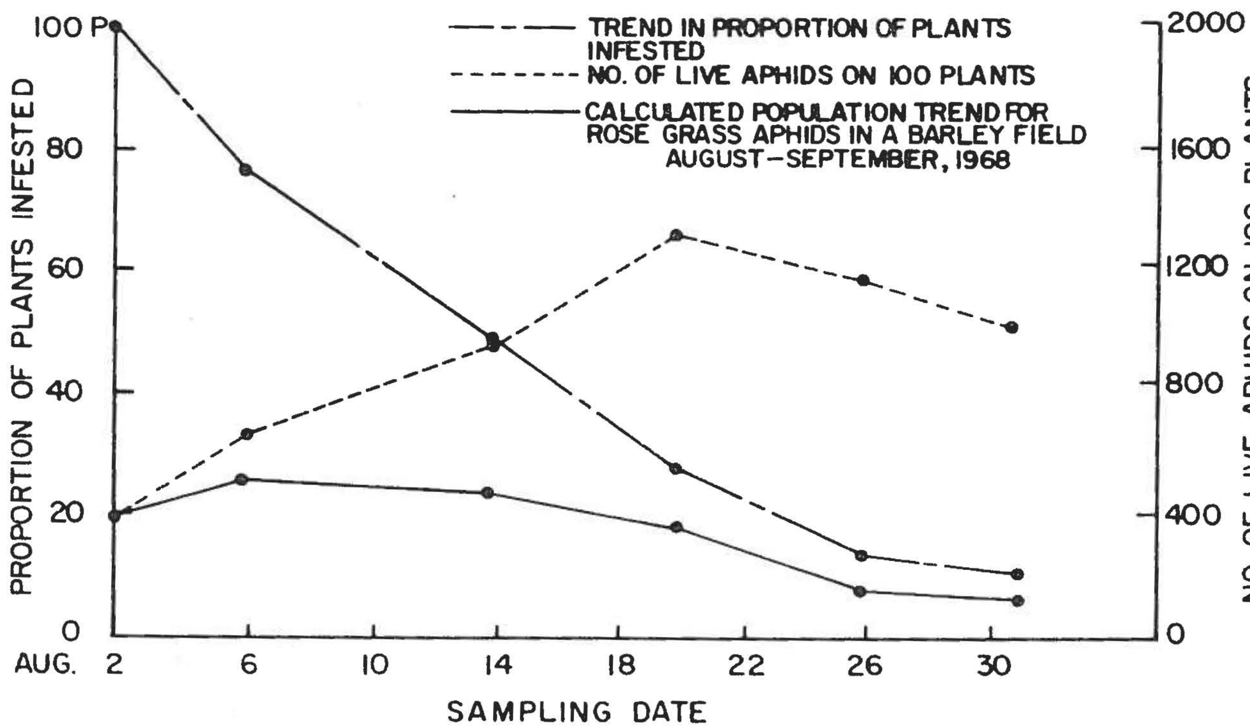

FIGURE 7. Population trend for rose grass aphids in a barley field August – September, 1968.

A STUDY OF THE VORACITY, FECUNDITY AND DEVELOPMENTAL RATES OF SOME COMMON LADY BEETLE PREDATORS OF APHIDS ON CEREAL CROPS IN MANITOBA

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ABSTRACT

Voracity, fecundity and developmental rates of *Adalia bipunctata* (L.), *Coccinella transversoguttata* Falderman, *Hippodamia convergens* Guerin-Meneville, *H. tredecimpunctata tibialis* (Say) and *H. parenthesis* (Say) were studied when fed in the laboratory on grain aphids *Rhopalosiphum maidis* (Fitch), *R. padi* (L.), *Macrosiphum avenae* (Fabricius), *Metopolophium dirhodum* (Walker) and *Schizaphis graminum* (Rondani). There was evidence that *H.t. tibialis* and *H. convergens* were somewhat more effective as predators of grain aphids than the other three species of coccinellids.

INTRODUCTION

Hodek (1966) edited a compendium of reports presented at a symposium on ecology of aphidophagous insects. There is apparently a lack of knowledge about the role of predators and parasites of aphids in western Canada. Studies have now started in Manitoba on this important group of beneficial insects, and especially on those associated with aphids on cereal crops. First results from these studies were discussed by Malyk (1971), and the following is a brief report on some of his studies on some common coccinellid predators.

METHODS

Samples of first or second generation adults of five species of lady beetles were obtained from the field: the twospotted lady beetle, *Adalia bipunctata* (L.); the transverse lady beetle, *Coccinella transversoguttata* Falderman; the convergent lady beetle, *Hippodamia convergens* Guerin-Meneville; the thirteenspotted lady beetle, *Hippodamia tredecimpunctata tibialis* (Say); and the parenthesis lady beetle, *Hippodamia parenthesis* (Say). They were kept in plastic cages constructed from pill vials 9 cm long and 6 cm diameter. Water was supplied; holes were made in the lid to allow air exchange, and the top was lined with cheesecloth to prevent escape of prey or predator. Coccinellid larvae used in experiments were reared from eggs laid in the laboratory. Cages containing predator and prey were kept in a growth cabinet at 22-24°C, 55% RH and a photoperiod of 16 hours of light and 8 hours of darkness.

Aphids were introduced into the cages on portions of leaves of Conquest barley. The aphid species used in tests were: the corn leaf aphid, *Rhopalosiphum maidis* (Fitch); the oat bird-cherry aphid, *Rhopalosiphum padi* (L.); the English grain aphid, *Macrosiphum (Sitobion) avenae* (Fabricius); the rose grass aphid, *Metopolophium dirhodum* (Walker); and the greenbug, *Schizaphis graminum* (Rondani).

RESULTS AND DISCUSSION

Samples of adult female beetles and third instar larval aphids were weighed, to determine relative sizes of the various species of predators and prey. Results for five species of lady beetles and five species of aphids are given in Table 1.

First generation adult females of five species of lady beetles from the field were fed for five days on third larval instars of each of five species of aphids. Sufficient prey were added every twelve hours to ensure that predators were never without food. Results are shown in Table 2, as an average for one adult female beetle for a 24 hour period. All five species of beetles consumed more of the three smaller and lighter species of aphids, *R. maidis*, *R. padi* and *S. graminum* than they did of the two larger and heavier aphids, *M. avenae* and *M. dirhodum*. The three largest beetles, *C. transversoguttata*, *H. convergens* and *H.t. tibialis* consumed equal amounts of *R. maidis* and of *R. padi*, but *C. transversoguttata* consumed more of *M. avenae* and *M. dirhodum* than did any of the other four lady beetles. In general, larger adult lady beetles consumed more aphids than did the smaller beetles, and greater numbers of the smaller aphids were eaten than of the heavier aphids.

Lady beetle larvae from eggs produced in the laboratory were fed through their developmental period of second, third and fourth instars, on third instar larval aphids of one species. First instar lady beetle larvae were not included because they were not big enough to ingest third instar aphids. Results are shown in Table 3 for four species of coccinellids feeding on five species of aphids. *C. transversoguttata* did not complete larval development on *M. avenae* or *M. dirhodum*, nor did *A. bipunctata* complete development on *M. dirhodum* (Table 5). The intriguing possibility of *M. dirodum* and *M. avenae* being toxic to one or more of the lady beetle species should be investigated further.

The number of aphids consumed increased with each coccinellid molt. Second and third instar larvae of *C. transversoguttata* consumed more of *R.maidis* than did any of the other species of lady beetles. *H. convergens*, *H.t. tibialis* and *A. bipunctata*, by instars, consumed about the same numbers of third instar larval aphids, except slightly fewer numbers of the larger aphids, *M. avenae* and *M. dirhodum*.

Fecundity of four lady beetle species was measured as number of eggs laid during the last five days of ten days subsisting on a diet of each of five aphid species (Table 4). *C. transversoguttata*, *H. convergens* and *H.t. tibialis* produced more eggs when fed on *R. maidis*, than did *A. bipunctata*. *H. convergens* and *H.t. tibialis* produced more eggs when fed on *M. avenae* and *M. dirhodum*, than did the other two coccinellid species. In general, *A. bipunctata* produced less eggs than did the other coccinellids, and numbers of eggs produced by any of the females varied with the species of aphid consumed.

While the data were being recorded for Table 3, a record was kept for the time spent in the larval and pupal stages. This information is shown in Table 5. Larval development of the two species of *Hippodamia* was faster than that of *A. bipunctata* or *C. transversoguttata* regardless of species of aphid consumed. *Hippodamia* spp. also were able to complete development on *M. dirhodum*, whereas the other two coccinellid species did not complete their fourth instars on *M. dirhodum*. Times spent in the pupal stage by *Hippodamia* spp. were the same except for *H.t.tibialis* which took longer when it had fed on *M. dirhodum*.

The numbers of replicates in the experiments were not large, but the use of Duncan's Multiple Range Test on the data increases confidence in the results shown in Tables 2 - 5. There is evidence that *H.t. tibialis* and *H. convergens* are the most effective predators on all the aphids studied. In addition to the data presented in Tables 2 - 5 on their voracity, fecundity and development, which is as good as or better than the other coccinellid species, they are the two most commonly found species of lady beetles in grain fields. In 1968 and 1969 when lady beetles were collected in barley fields from straight line 100 foot transects, *H.t. tibialis* represented 52.0 and 62.4 percent respectively of total beetles collected, and *H. convergens*, represented 43.8 and 14.6 percent respectively.

ACKNOWLEDGEMENTS

The financial assistance from an Operating Grant from the Canada Department of Agriculture is gratefully acknowledged.

REFERENCES

Hodek, Ivo 1966. [Editor]. Ecology of Aphidophagous Insects. Dr. W. Junk, Publisher, The Hague, Netherlands. 360 pp.

Malyk, M.R. 1971. Factors affecting the numbers of aphids on grain crops in Manitoba with observations on aphid predators and parasites. M.Sc. Thesis, University of Manitoba, Winnipeg.

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TABLE 1

Average live weights of five adult female lady beetle species and five third instar aphid species (five replicates for each species)

Lady Beetle species	Weight (milligrams)	Aphid species	Weight (micrograms)
Hippodamia parenthesis	11.9	*Rhopalosiphum maidis*	130
Adalia bipunctata	12.4	*Rhopalosiphum padi*	160
Hippodamia tredecimpunctata tibialis	13.5	*Schizaphis graminum*	195
Hippodamia convergens	19.6	*Macrosiphum avenae*	355
Coccinella transversoguttata	32.7	*Metopolophium dirhodum*	375

TABLE 2

Average number of third instar larval aphids eaten by one adult female lady beetle in 24 hours. Average of 5 replicates

		Number of aphids eaten in 24 hours	
Lady Beetle	Aphid	Mean	Range
Coccinella transversoguttata	*Rhopalosiphum maidis*	180 a	166-194
	Rhopalosiphum padi	173 ab	168-176
	Schizaphis graminum	169 ab	165-173
	Macrosiphum avenae	125 de	111-135
	Metopolophium dirhodum	131 d	113-139
Hippodamia convergens	*R. maidis*	159 ab	152-167
	R. padi	151 bc	123-164
	S. graminum	137 cd	131-152
	M. avenae	109 fg	94-127
	M. dirhodum	105 fg	103-108
Hippodamia tredecimpunctata tibialis	*R. maidis*	164 ab	147-182
	R. padi	155 bc	135-179
	S. graminum	151 bc	123-167
	M. avenae	108 fg	103-115
	M. dirhodum	111 ef	104-122
Adalia bipunctata	*R. maidis*	103 f-h	94-112
	R. padi	96 gh	85-107
	S. graminum	91 hi	83-103
	M. avenae	82 ij	74-94
	M. dirhodum	80 ij	74-86
Hippodamia parenthesis	*R. maidis*	81 ij	67-94
	R. padi	78 j	67-95
	S. graminum	72 j	68-86
	M. avenae	60 k	50-67
	M. dirhodum	58 k	49-69

[a] Numbers followed by the same letter are not significantly different at the 5% level using Duncan's multiple range test.

TABLE 3

Average numbers of third instar larval aphids consumed by second, third or fourth instar larval lady beetles. Average of 3 replicates

Lady Beetle	Aphid	Number eaten Second Instar Mean	 Range	 Third Instar Mean	 Range	 Fourth Instar Mean	 Range
Coccinella transversoguttata	*Rhopalosiphum maidis*	66 f-k	62-71	103 b-d	96-112	144 a	138-150
	Rhopalosiphum padi	44 n-q	38-50	89 c-f	75-98	133 ab	120-156
	Schizaphis graminum	46 m-p	39-54	79 d-i	66-97	126 ab	102-153
	Macrosiphum avenae	34 q-t	31-37	48 l-p	43-56	66 f-k	57-81
	Metopolophium dirhodum	40 o-r	31-47	56 j-n	51-62	76 d-i	62-84
Hippodamia convergens	*R. maidis*	34 q-t	31-38	69 f-k	54-82	90 c-f	80-103
	R. padi	27 t-v	22-31	59 h-m	42-71	83 c-g	66-98
	S. graminum	29 s-u	20-35	54 j-o	42-61	79 d-i	63-95
	M. avenae	29 s-u	22-25	42 n-r	35-52	63 g-l	53-72
	M. dirhodum	21 v	18-24	41 o-r	36-49	60 h-m	51-69
Hippodamia tredecimpunctata tibialis	*R. maidis*	40 o-r	33-46	72 e-j	68-77	109 a-c	98-122
	R. padi	38 p-s	31-47	69 f-k	58-77	98 c-e	89-104
	S. graminum	38 p-s	30-43	72 e-j	65-76	100 b-d	85-113
	M. avenae	33 q-u	30-38	58 i-m	46-66	87 c-f	78-94
	M. dirhodum	32 r-u	29-35	58 i-m	53-64	77 d-i	68-89
Adalia bipunctata	*R. maidis*	38 p-s	36-41	68 f-k	61-72	82 c-g	75-88
	R. padi	37 p-s	34-42	62 g-l	58-65	81 c-h	78-86
	S. graminum	33 q-u	30-37	54 j-o	49-62	81 c-h	69-88
	M. avenae	25 u-v	21-30	52 k-o	43-61	66 f-k	57-76
	M. dirhodum	25 u-v	19-31	48 l-p	39-56	58 i-m	46-67

[a] Numbers followed by the same letter are not significantly different at the 5% level using Duncan's multiple range test.

TABLE 4

Number of eggs laid during the sixth to tenth days inclusive, by four lady beetle species while subsisting for ten days on a diet of each of five aphid species. Average of 5 replicates

Lady Beetle	Aphid	No. of eggs in 5 days	
		Mean	Range
Coccinella transversoguttata	*Rhopalosiphum maidis*	116 ab	91-131
	Rhopalosiphum padi	100 b-e	87-115
	Schizaphis graminum	98 b-f	90-108
	Macrosiphum avenae	25 k	22-56
	Metopolophium dirhodum	51 ij	21-70
Hippodamia convergens	*R. maidis*	110 a-c	106-119
	R. padi	98 b-f	85-109
	S. graminum	106 a-d	95-108
	M. avenae	96 c-f	84-117
	M. dirhodum	82 e-g	73-95
Hippodamia tredecimpunctata tibialis	*R. maidis*	123 a	101-151
	R. padi	90 d-g	82-103
	S. graminum	89 d-g	72-108
	M. avenae	88 d-g	79-89
	M. dirhodum	59 hi	38-82
Adalia bipunctata	*R. maidis*	79 fg	61-111
	R. padi	76 gh	67-96
	S. graminum	35 jk	17-61
	M. avenae	33 jk	22-54
	M. dirhodum	42 i-k	28-57

[a] Numbers followed by the same letter are not significantly different at the 5% level using Duncan's multiple range test.

TABLE 5

The average lengths of larval and pupal development for each of four species of lady beetles reared on each of five species of aphids.

Average of 3 replicates

Lady Beetle	Aphid	No. of days in larval stage		No. of days in pupal stage	
		Mean	Range	Mean	Range
Coccinella	*Rhopalosiphum maidis*	13.3	13-14	6 d	5-7
transversoguttata	*Rhopalosiphum padi*	14	—	5.3 b-d	5-6
	Schizaphis graminum	14.7	14-15	5.0 bc	4-6
	Macrosiphum avenae	*	—	*	—
	Metopolophium dirhodum	*	—	*	—
Hippodamia	*R. maidis*	10 a	—	4 a	—
convergens	*R. padi*	10 a	—	4 a	—
	S. graminum	10 a	—	4 a	—
	M. avenae	10 a	—	4 a	—
	M. dirhodum	10 a	—	4 a	—
Hippodamia	*R. maidis*	10 a	9-10	4.7 ab	4-5
tredecimpunctata	*R. padi*	11 b	—	4 a	—
tibialis	*S. graminum*	10.7 b	10-11	4 a	—
	M. avenae	10.3 ab	10-11	4 a	—
	M. dirhodum	10.3 ab	10-11	5.7 cd	5-6
Adalia	*R. maidis*	12 c	—	5 bc	—
bipunctata	*R. padi*	12 c	—	5 bc	—
	S. graminum	12 c	—	6 d	—
	M. avenae	12 c	—	6 d	—
	M. dirhodum	**	—	**	—

* Died in fourth instar, age 17 days

** Died in fourth instar, age 12 days

a Numbers followed by the same letter, in each column, are not significantly different at the 5% level using Duncan's multiple range test.

ADDITIONS TO THE LIBRARY OF THE ENTOMOLOGICAL SOCIETY OF MANITOBA

Acridological abstracts, no.7-8, 1970; no.1-4, 1971. (Anti-Locust Research Centre, London.)

Acta entomologica musei nationalis Pragae, v.38, 1969.

American Museum of Natural History, New York. American Museum novitates, no.2489, 1972.

American Museum of Natural History, New York. Bulletin, v.147, art.4, 1972.

Annales de zoologie — ecologie animale, v.3, 1971; v.4, no.1, 1972. (France. Institut national de la recherche agronomique, Paris.)

Annales zoologici, v.28, no.4-17, 1970-71; v.29, no.1, 1971. (Polska akademia nauk. Instytut zoologiczny, Warsaw.)

Annals of the Entomological Society of Quebec, v.16, 1971; v.17, no.1, 1972.

Bulletin analytique d'entomologie medicale et veterinaire, v.18, no.2-12, 1971; v.19, no.1-2, 1972. (France. Office de la recherche scientifique et technique d'outre-mer, Paris.)

California. Bureau of Entomology. Occasional papers, no.1-18, 1957-69.

California. University, Berkeley. Publications in entomology, v.62-67, 1970-71.

Entomologische berichten, v.30, no.9-12, 1970; v.31, 1971; v.32, no.1-2, 1972. (Nederlandsche Entomologische Vereeniging, 's-Gravenhage.)

Fragmenta faunistica, v.16, no.7-13, 1970-71; v.17, 1971. (Polska akademia nauk. Instytut zoologiczny, Warsaw.)

Journal of the Entomological Society of British Columbia, v.67-68, 1970-71.

Naples. Universita. Laboratorio de entomologia agraria. Bollettina, v.28, 1970.

Nebraska. University. College of Agriculture. (Reprint material, 1971.)

New York (State). Agricultural Experiment Station, Ithaca. Food and life sciences bulletin, no.5, 1970.

New York (State). Agricultural Experiment Station, Ithaca. Search agriculture, v.1, no.1, 3-8, 12, 1970-71.

New York (State). College of Agriculture. Bulletin 1226, 1971.

New York (State). College of Agriculture. Information bulletin 7, 1971.

Poeyana, ser. A, no.79-93, 1971. (Cuba. Comision Nacional de la Academia de Ciencias. Instituto de Biología, Havana.)

Poljoprivredna znanstvena smotra; agriculturae conspectus scientificus, v.27, 1971. (Zagreb. Univerzitet. Poljoprivrednosumarski fakultet.)

Proceedings of the Iowa Academy of Science, v.76-78, 1969-72.

Rio de Janeiro. Museu Nacional. Boletim; nova serie, zoologia, no.281-284, 1971.

Rio de Janeiro. Museu Nacional. (Reprint material, 1971.)

Studi sassaressi; sezione III, v.18, 1970. (Sassari, Sardinia. Universita. Facolta di agraria.)

Swedish Journal of Agricultural Research, v.1, 1971.

Uruguay. Instituto de Investigion de Ciencias Biológicas, Montevideo. (Publication list, v.2, 1969-70.)

Zastita bilja; Plant protection, no.102-113, 1968-71. (Savenzni institut za zastitu bilja, Belgrade.)

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