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RELATIVE ABUNDANCE OF THE ROOT MAGGOTS *DELIA RADICUM* (L.) AND *D. FLORALIS* (FALLÉN) (DIPTERA: ANTHOMYIIDAE) AS PESTS OF CANOLA IN ALBERTA

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Quaestiones Entomologicae
22: 253-260 1986

ABSTRACT

The relative abundance of adults of the root maggots Delia radicum *(L.) (=*brassicae*) and* D. floralis *(Fallén) (=* crucifera*) in Alberta has been mapped, mainly on the basis of samples from canola fields.* D. radicum *is the more abundant species mainly in the NW Agricultural Region,* D. floralis *in much of the NE and throughout the Peace River Agricultural Regions. Both species are univoltine in these Regions. Continuous monitoring data for Smoky Lake during 1982 indicate that adults of* D. radicum *started to appear earlier and were present for a more extended period than were those of* D. floralis, *but numbers of both species peaked at about the same time (June 20).*

The pattern of relative abundance is not significantly correlated with air temperatures, but is highly correlated with differences in summer precipitation. The area where D. radicum *is predominant has mean June-August precipitation approaching or exceeding 250 mm, while values for the area where* D. floralis *is predominant are generally lower. The hypothesis that larvae of the two species differ with respect to moisture response is suggested for experimental testing.*

RÉSUMÉ

Une représentation cartographique de l'abondance relative des adultes des mouches des racines Delia radicum *(L.) (=brassicae) et* D. floralis *(Fallên) (=crucifera), déterminée principalement à partir d'échantillonages dans les champs de Canola, est produite pour l'Alberta.* D. radicum *est l'espèce la plus abondante principalement dans la Région Agricole Nord-Ouest. Pour sa part,* D. floralis *est plus abondante dans la majeure partie de la Région Nord-Est ainsi qu'au travers de la Région Agricole Peace River. Les deux espèces sont univoltines dans ces régions. L'observation continue des éehantillons de la région de Smoky Lake pendant l'année 1982, indique que les adultes de* D. radicum *font une apparition hâtive et sont présents pour une période plus étendue que ceux adultes de* D. floralis. *Cependant, le nombre des individus de chacune des espèces était à son maximum presqu' à la même periode (20 juin).*

La progression de l'abondance relative n'est pas significativement corrélée à la fluctuation de la température de l'air, mais bien avec la variation des précipitations estivales. La région où D. radicum *est dominante reçoit, pour les mois de juin à août, une précipitation moyenne approchant ou excédant 250 mm, comparativement à une valeur généralement inférieure pour la région dominée par* D. floralis. *L'hypothèse que les larves des deux espèces réagissent de façon différente à l'humidité, est proposée pour épreuves expérimentales.*

INTRODUCTION

The cabbage maggot, *Delia radicum* (L.) (= *brassicae* Wiedemann, *brassicae* Bouché), is a significant pest of canola[1] in the NW Agricultural Region of Alberta (Griffiths, 1985; 1986a).

[1]Canola is defined as rapeseed cultivars of *Brassica campestris* L. and *B. napus* L. with < 5% erucic acid and < 3 mg glucosinolates/g of oil-free meal. This is the only cole crop widely grown on a field scale in Alberta.

But in some parts of Alberta this species is replaced by the turnip maggot, *D. floralis* (Fallén) (= *crucifera* Huckett), as the most abundant root maggot on canola and other cole crops (Brassicaceae/Cruciferae). Jørgensen's (1976) work in Denmark suggests that the relative abundance of these species in particular districts is stable, and hence can be mapped. I present here the first such map for Alberta (and North America), and discuss possible explanations for the pattern shown in terms of biological and climatic factors (see also Griffiths, 1986b).

The summary of earlier information regarding *D. floralis* as a pest insect in Canada by Beirne (1971) is misleading due to confusion of records of *D. floralis* with those of *D. florilega* (Zetterstedt). Beirne may have assumed that he was dealing with variant spellings of a single name. In fact, these names refer to quite different species, *florilega* belonging to the seedling maggot complex (*Delia platura* group) and not restricted to crucifers. Part of the information attributed to *D. floralis* by Beirne in fact pertains to *D. florilega*.

MATERIAL AND METHODS

Details of trapping methods have been given in recent publications (Griffiths, 1985; 1986a).

Two canola fields in the Smoky Lake district, where both *D. radicum* and *D. floralis* are common, were continuously monitored by H.J. Liu and C. Prockiw during 1982. The data for each field consist of catches of 12 sticky traps + one water trap set along field margins.

In the light of this Smoky Lake data I made a geographical survey of the relative abundance of *D. radicum* and *D. floralis* by obtaining single samples of adult flies for periods from about mid-June to the beginning of July. Four bowls containing Galt's solution were set along a sheltered margin of a canola field at each site. The survey was conducted in the NE and NW Regions during 1984, and in the Peace River and NW Regions during 1985. Most of the data mapped (Fig. 1) consist of single samples collected in this way. Continuous monitoring data were available only for Smoky Lake (1982), Morinville (1982–84) and SW Westlock (1983). The data for South Edmonton (1985) consist of emergence trap catches from the previous season's canola plots together with flies reared from *Thlaspi arvense* L. (an alternate host for both species of *Delia*). Flies from the market garden area in NE Edmonton were obtained by bowl trapping and by rearing from several hosts (received from R.S. McDonald and M. Steiner).

Computer-generated maps of precipitation, summer moisture deficit, temperature and seasonal growing degree days (above 5°C) in Alberta were provided by Serge Dupuis (Climate Unit, Alberta Energy and Natural Recources). Relative percentages of each species in total catches of the two were compared with this data, both by visual inspection of the maps and by calculation of correlation coefficients. In view of the non-normal distribution of the relative percentages, I used Spearman's rank correlation coefficient (r^s), a non-parametric statistic.

RESULTS

Relative Abundance (Fig. 1)

D. floralis is the abundant species throughout the Peace River Region. *D. radicum* was entirely lacking from samples from this Region, with the exception of a sample taken 11 km ESE Debolt in the extreme South. The other area where *D. floralis* is more abundant is in the NE Agricultural Region, extending from Willingdon through Elk Point and Vermilion to the Saskatchewan border. Both species were represented in similar numbers in samples from four districts (Bonnyville, Smoky Lake and Bellis in the NE Region, Athabasca in the NW Region).

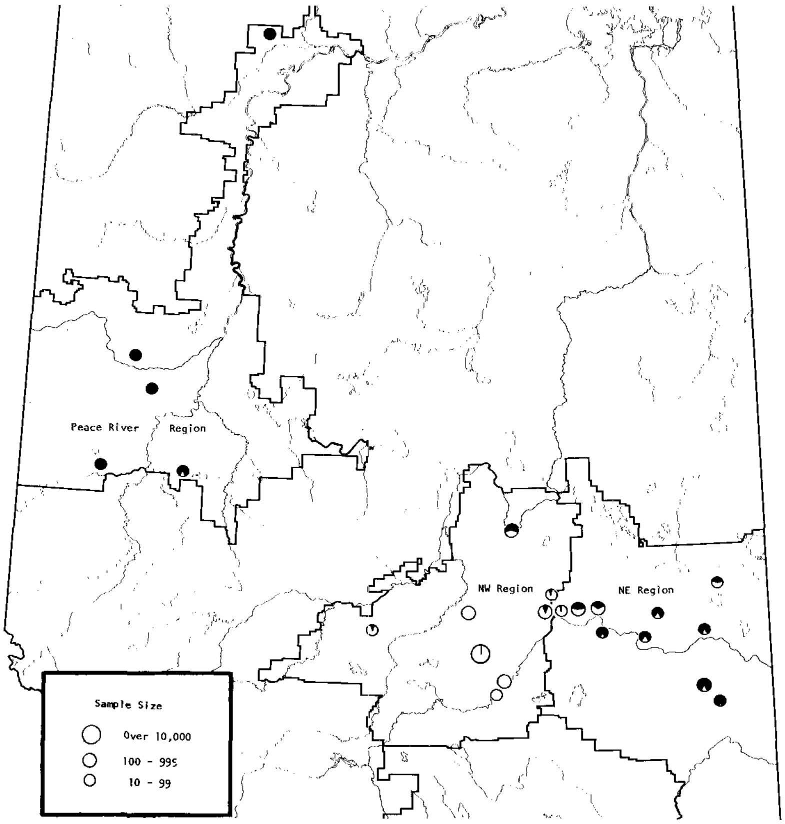

Fig. 1. Relative abundance of adult *Delia floralis* (Fallén) and *D. radicum* (L.) in canola fields in Northern Alberta. The black portion of the circles represents the proportion of *D. floralis*, the white portion that of *D. radicum*, in total catches of the two species. Only sites with a minimum sample size of 10 have been mapped.

In most of the NW Region extending to Waskatenau just inside the NE Region, *D. radicum* is by far the more abundant species.

Comparative Phenology

A comparison between the adult phenology of *D. radicum* and *D. floralis* in canola fields is provided by data for the Smoky Lake district (Fig. 2), where both species are abundant. Two fields in this district were continuously monitored during 1982. *D. floralis* first appeared in samples for June 4–7, about three weeks later than the first appearance of *D. radicum* (already present in the sample for May 11–14). This difference in time of first appearance was not, however, associated with a similar difference in peaks of abundance, for numbers of both species showed a pronounced peak about June 20. During July adults of both species continued to be taken, but in declining numbers.

The phenology of the immature stages of *D. radicum* in Alberta has been documented elsewhere (Griffiths, 1985; 1986a). Oviposition on canola commences at about the time the crop starts to bolt (about mid-June). Larvae inflict root damage mainly during July, by the end of which most have pupated. Most puparia overwinter, and adults of the relatively insignificant

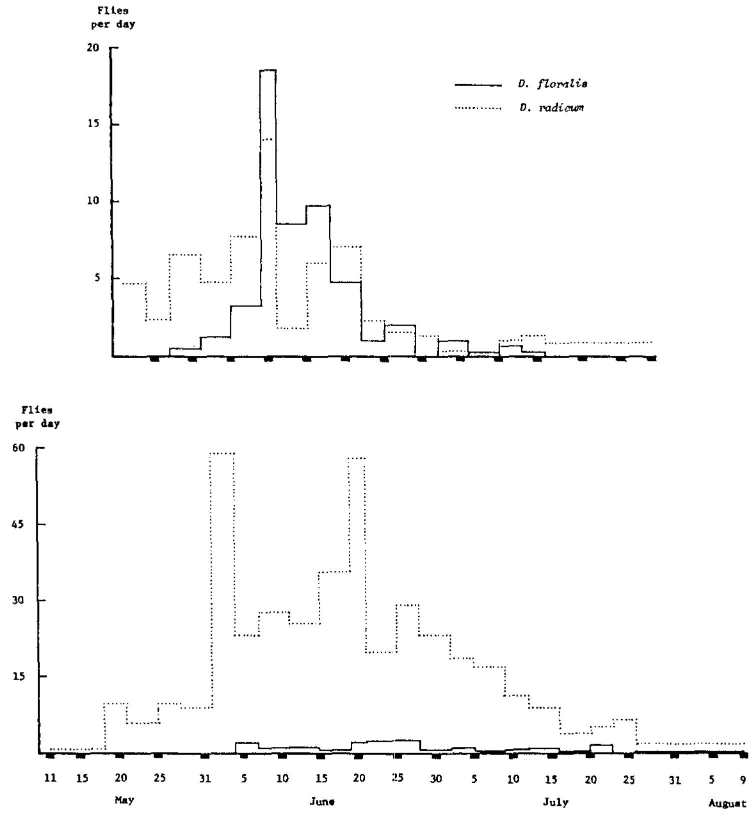

Fig. 2. Captures of adults of *Delia floralis* (Fallén) and *D. radicum* (L.) on margins of canola fields at two sites near Smoky Lake, Alberta (1982) (12 sticky traps + one water trap at each site).

second generation do not oviposit on canola.

D. floralis appears to be fully univoltine in Alberta, since no adults have been obtained from rearing samples during the same season. While available data on the larval phenology are inadequate (see Griffiths, 1986b), a significant difference from that of *D. radicum* seems unlikely in view of the synchronous peaks of adult abundance.

Correlation of Relative Abundance with Climatic Factors

Significant correlations between the pattern of relative abundance and air temperatures have not been found. The parameters tested without significant result included annual means, annual extremes, monthly means for May to July, and seasonal growing degree days. The NE, NW and Peace River Agricultural Regions of Alberta have similar air temperatures thoughout the year, since isotherms shift northward in Western Alberta. Seasonal growing degree days (above 5°C) range from 900 to 1300 in all three regions.

The pattern of relative abundance is correlated not with temperature but with precipitation, especially summer precipitation. The area where *D. radicum* is predominant has higher summer rainfall and lower summer moisture deficit. The rank correlation coefficient (r^s) for

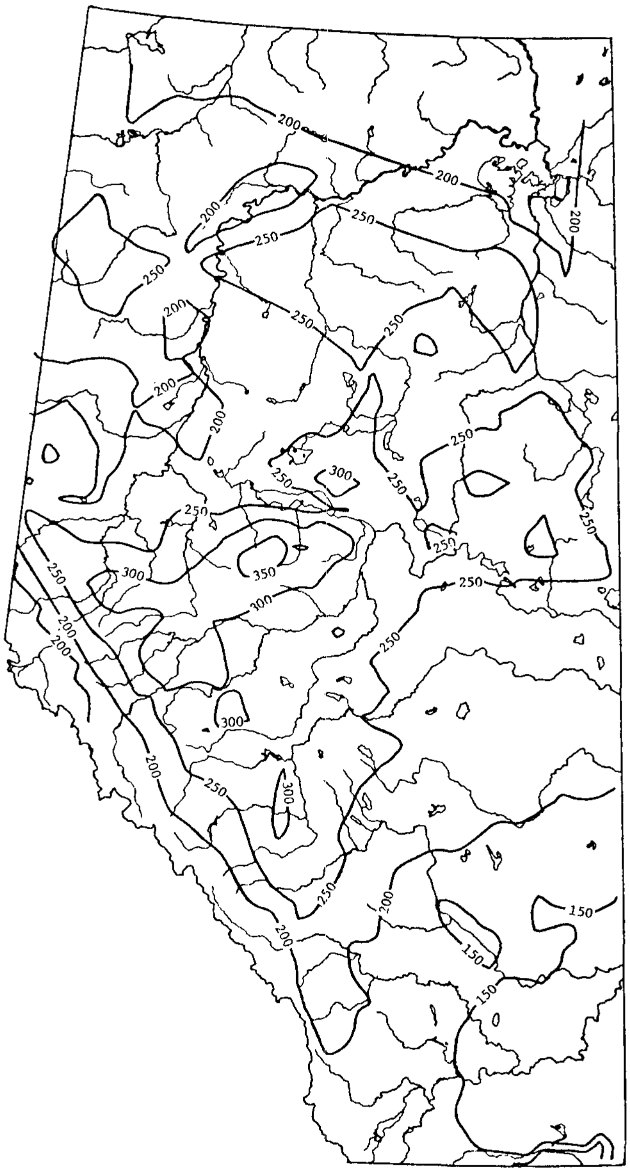

Fig. 3. June + July + August precipitation (mm) in Alberta. Source: Atmospheric Environment Service normals (1951–1980). Mapping by: Climate Unit, Resource Evaluation and Planning, Alberta Energy and Natural Resources.

sites shown in Fig. 1 between percentage of either species (in catches of both combined) and mean June-August precipitation (1951-1980) has been calculated as 0.80 ($P < 0.001$).

The area where *D. radicum* is predominant has mean June-August precipitation approaching or exceeding 250 mm (compare Figs. 1 and 3), and a summer moisture deficit (May-August) ranging from 100 to slightly more than 200 mm. In the area where *D. floralis* is predominant, mean June-August precipitation is generally lower, and summer moisture deficits are generally well in excess of 200 mm (calculated values 210–410 mm).

DISCUSSION

Relative Abundance

In Europe *Delia floralis* is the main root maggot pest of cole crops in Northern Scotland (Morrison, 1938) and in most of Fennoscandia, including part of Denmark (Lundblad, 1933; Wagn, 1953; Rygg, 1962; Varis, 1967; Jørgensen, 1976; Havukkala *et al.*, 1984). South of these areas the main pest of cole crops is *D. radicum*. Jørgensen (1976) has mapped the areas where *D. floralis* is a pest in Denmark.

In North America *D. floralis* is a pest of cole crops in Alaska, where *D. radicum* does not occur (Washburn, 1953; Bleicher, 1981). Brooks (1951) reported that *D. floralis* (as *crucifera*) was a major pest throughout the Canadian Prairie Provinces, especially in the woodland and parkland sections. But his statement was too general, since *D. radicum* has since been shown to be the predominent species in the Winnipeg district (Allen, 1964), as well as in the NW Agricultural Region of Alberta. The present data demonstrate that *D. floralis* is the predominant species in Alberta only in the NE and Peace River Regions. Its presence in the Peace River Region long predates rapeseed cultivation, since Strickland (1938) reported that "in 1929 this fly destroyed large areas of stinkweed (*T. arvense*) in the Peace River district". Stewart (1955) reported that *D. floralis* was a serious pest of cole crops in most of Saskatchewan (including irrigated farms in the prairie area), but that at Regina Beach the pest species was *D. radicum*.

In areas of Southern British Columbia, Ontario and Québec, where multivoltine populations of *D. radicum* are serious pests, *D. floralis* does not occur. It has also not been reported in the contiguous United States, where the range of *D. radicum* extends as far south as San Francisco and North Carolina.

Comparative Phenology

D. radicum varies considerably with respect to emergence dates and the number of generations in different parts of its wide holarctic range (Griffiths, 1986a). On the other hand, *D. floralis* is univoltine[2] everywhere except for a restricted area of Denmark, where Jørgensen has demonstrated the presence of a bivoltine strain. In most of Fennoscandia where the two species coexist, they show different phenologies (*D. radicum* fully or partly bivoltine, with adults emerging earlier from overwintered puparia; *D. floralis* univoltine and later emerging) (Rygg, 1962; Varis, 1967; Havukkala *et al.*, 1984). Because of these phenological differences, larvae of *D. radicum* are the main cause of damage to early maturing crops (such as radish and cabbage), while larvae of *D. floralis* predominate on slower growing root crops. This is the source of the distinction in the common names ("cabbage maggot" for *D. radicum*, "turnip maggot" for *D. floralis*).

In Alberta there is much less phenological difference. Both species are univoltine (predominantly so for *D. radicum*, strictly so for *D. floralis*). Both have evolved similar phenology in adaptation to exploiting canola crops, with adult numbers peaking at about the same time. The only demonstrated difference between them is in the extent of the period of adult emergence. In *D. radicum* the emergence period is very extended (from mid-May to mid-July), indicative of genetic heterogeneity with respect to emergence (Griffiths, 1986a). Early emerged females oviposit on early cole crops and weeds growing as winter annuals

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[2]Brooks (1951) seems to have thought that there could be a partial second generation of *D. floralis* (as *crucifera*) in Canada in some years, since he stated it to have "1 to 1½ generations" in his Table I. But it is doubtful that he had evidence for the existence of a partial second generation, since his colleague Stewart (1955) does not mention it.

(especially *Thlaspi arvense* L.) from late May, but they do not oviposit on canola until this begins to bolt in mid-June. By this time adults of *D. floralis* have also appeared. Thus, the earlier appearance of adults of *D. radicum* may result in this species attacking early maturing crops (such as radish and cabbage) at an earlier date than does *D. floralis*; but it is doubtful whether there is any significant difference in the time at which either species commences to oviposit on canola. The differences in relative abundance of the two species in canola fields in different regions of Alberta thus cannot be attributed to any known phenological difference.

Genetic differences with respect to emergence, as demonstrated experimentally for *D. radicum* (Finch and Colleir, 1983), may also occur between populations of *D. floralis*. Bleicher (1981) states that in the Matanuska Valley of Alaska emergence of *D. floralis* may begin as early as June 1 or as late as June 11 according to season. This is consistent with the data for Smoky Lake, Alberta (Fig. 2). However, Brooks (1951) and Stewart (1955) stated that the flies emerge about a month later (from early July to early August). Unfortunately, they did not state where their observations were made. But it will not be surprising if the existence of late-emerging populations in North America is confirmed, since even later emergence periods (with August peaks) are reported for unvoltine populations in Denmark (Wagn, 1953; Jørgensen, 1976).

Correlation of Relative Abundance with Climatic Factors

Since *D. radicum* and *D. floralis* have evolved a similar phenological pattern in Alberta and exploit the same food resources, I am left to suppose that geographical differences in their relative abundance indicate differences in relative dominance determined by response to climatic factors.

My finding that the relative abundance of these two species in Alberta is strongly correlated with summer precipitation and summer moisture deficit suggests that larvae of *D. radicum* may be adapted to moister soil than are those of *D. floralis*. The observations of Jørgensen (1976) in Denmark seem confirmatory. He reports that in Jutland *D. floralis* is virtually confined to sandy (*i.e.*, well drained) soils, while *D. radicum* is abundant on heavier soils.

Laboratory studies will be needed to test the hypothesis here advanced that larvae of *D. radicum* and *D. floralis* differ with respect to moisture response. Although favourable conditions of temperature and moisture for *D. radicum* have been determined experimentally (*e.g.*, Read, 1965), no comparable data have yet been published for *D. floralis*.

ACKNOWLEDGEMENTS

I am most grateful to the following for assistance in the work reported in this paper: to Dr. George E. Ball for obrtaining financial support from Farming for the Future; to Dr. Helen J. Liu and Ms. Constance E. Prockiw for obtaining samples from Smoky Lake in 1982; to Mr. Jim W. Jones for collecting some of the samples of adult flies from the NE and NW Agricultural Regions during 1984 and 1985; to Mr. Serge Dupuis for generating maps from the computerized climatic data base developed by Alberta Energy and Natural Resources; and to Dr. John R. Spence and Dr. Bruce S. Heming for commenting on a first draft of this paper.

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