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THE POLLINATION OF RED CLOVER AND LUCERNE IN NEW ZEALAND

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SUMMARY

The reliance of red clover and lucerne on insect pollinators and the history of the introduction to New Zealand of the latter are discussed.

Only three species of bumble bees, *Bombus terrestris* (L.), *B. ruderatus* (Fab.), *B. subterraneus* subsp. *latreillellus* (Kirby), were thought to have become established but a recent survey shows that a fourth species, *B. hortorum* (L.) is present and widespread east of the main divide and south of Balcairn in north Canterbury. Distribution, life cycles, seasonal abundance of food and its influence on local abundance of species, tongue length and foraging behaviour in relation to relative efficiency of *B. terrestris* and *B. ruderatus* as pollinators of these two crops, are discussed. The efficiency of honey-bees and their future use in New Zealand as pollinators of red clover as well as further studies of bumblebees in relation to this problem are considered.

BOTH RED CLOVER AND LUCERNE are leguminous plants and they have flowers with specialized pollination mechanisms which require relatively heavy insects to operate them. The larger bees are the insects best adapted to meet these requirements. There are 20 species of bees native to New Zealand (Tillyard, 1926), but none of these are large and they seldom occur in sufficient numbers to be of any consequence as pollinators of these crops. Neither have any other native insects been shown to pollinate either of these crops effectively.

Much red clover was used in the new pastures sown by the early settlers, but although honey-bees had been brought to New Zealand as early as 1839, seed set was negligible—certainly none set on a commercial basis. About the middle of last century, Darwin drew attention to the efficacy of bumblebees as pollinators of red clover, and so it was decided to introduce some of these insects into New Zealand for this purpose. Various attempts from 1870 onwards were made to establish bumble bees, both by the Canterbury Acclimatisation Society and private individuals, but it was not until 1885 that success was achieved. From a consignment of 93 queens liberated near Christchurch in that year by the Canterbury Acclimatisation Society, a thriving population built up and spread throughout the island; nests and queens were also sent to the North Island, where they quickly became established.

The effect on seed setting of red clover was immediate and spectacular. By 1889 yields of 4 cwt or 5 cwt per acre were reported from Lincoln College and a report in the *Lyttelton Times* dated July 22, 1889, reads: "Ellesmere: A large quantity of clover seed has been grown in the district this year. At the present time, it is the most payable crop a farmer can grow; one man cleared, at Irwell, over £13 an acre with his clover crop". Seed at that time was worth sixpence per pound; that means a yield in the region of 500 lb per acre.

Not content with this, however, farmer organizations were pressing for the introduction of further species in order to increase the seed yields. As no record had been kept of the species introduced, samples of those present were sent to England in 1895 for identification. Two species only were found to have established — *Bombus terrestris* (L.) and *B. ruderatus* (Fab.), (Gurr, 1957b). More bumble-bees were introduced in 1906—this time by the Canterbury Agricultural and Pastoral Society—and 143 queens were liberated. Again no accurate account was kept of species liberated (Hopkins, 1914).

Whenever several bad seasons follow one another, farmers convince themselves that the yields of red clover are declining, but, although fluctuations occur, no continuous downward trend has been demonstrated. As yields continued to fluctuate, so did agitation for further introductions of bumble-bees. In response to these continued demands, in 1948, some 400 queens of suitable species were collected in England by Dr R. Cumber and were ready for despatch, but permission to introduce them into the country was refused on the grounds that they might be carriers of acarine disease—a disease that has made disastrous inroads into the honey-bee population of Great Britain, but has so far not been recorded from New Zealand. The risk was almost negligible, but the caution was understandable. Briefly, that is the history of our attempts to solve the problem of pollination of red clover in this country, and, until 1952, the only solution to the problem suggested whenever the matter was raised was, "Let us introduce more species of bumble-bees".

In 1952, the matter of introductions was again raised, and it was decided that the Entomology Division, D.S.I.R., should undertake an investigation into the basic entomological factors affecting seed set in red clover before any further introductions were made. This task was assigned to the writer, who found the existing knowledge on the matter to be a heterogeneous mixture of hearsay and folk-lore. What little published material there was, especially on species present, seemed to be contradictory. To clarify this position, a survey was started in 1953. Collections were made from 265 different localities in the South Island, many of which were visited several times, both in the spring and the autumn. Some 6,000 specimens were taken.

Although this has been time-consuming and slow, it has established that four species, *B. terrestris, B. ruderatus, B. hortorum* (L.), and *B. subterraneus* (L.) subsp. *latreillellus* (Kirby) are present (Gurr, 1957b), whereas two surveys made as late as 1948 (Dumbleton, 1949) and 1949 (Montgomery 1951), found only three species present. The fourth species (*B. hortorum*) found on the recent survey was shown to be present and plentiful on the eastern side of the main divide from Balcairn in north Canterbury, to as far south as Invercargill. This species was high on the priority list for introduction, yet was found to be already well established here. It is the writer's opinion that this was one of the species liberated in 1906.

A fifth species, *B. lucorum* (L.), claimed to be present by McBurney (1941) has been very thoroughly searched for, and although claimed to be second only to *B. terrestris* in numbers in Canterbury, it could not be found. The only specimen labelled *B. lucorum* in what is left of McBurney's collection at Lincoln College is definitely *B. terrestris*, and it is now reasonably certain that McBurney's claim was based on a mis-identification.

Two others pecies, *B. lapidarius* (L.) and *B. derhamellus* (Kirby) (syn. for *B. ruderarius* (Muller) were liberated in 1906. Both these species are conspicuous insects, black with the last three abdominal segments of the abdomen red, quite distinct from the familiar yellow-striped bumble-bees whose terminal abdominal segments are white or fawn. The possibility that such conspicuous insects could have remained unnoticed for the past 50 years is so remote that it can be safely assumed they are not present. A preliminary account of this part of the survey is given by Gurr (1957b).

The distribution of the four species present shown by the survey is, *B. terrestris* and *B. ruderatus* present throughout the South Island, while *B. hortorum* and *B. subterraneus* subsp. *latereillellus* are confined to the eastern side of the main divide south of Balcairn in north Canterbury. While *B. hortorum* is

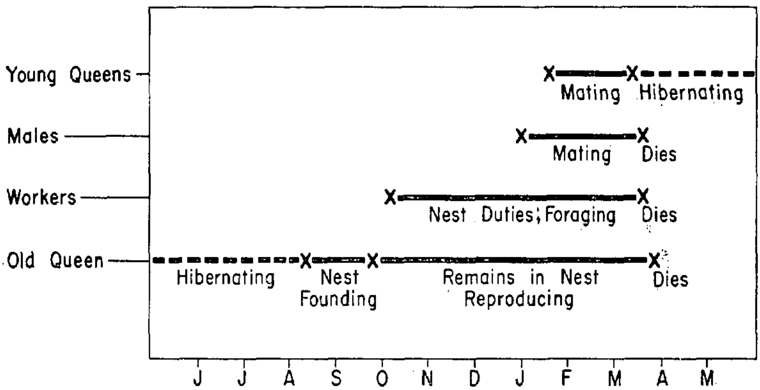

Fig. 1: A typical life cycle of bumble-bees in New Zealand.

relatively evenly distributed throughout its range, *B. subterraneus* is almost confined to the upland basins and foothills of the Southern Alps. It is plentiful only in the Mackenzie country; elsewhere it is rare.

Since the Mackenzie country is claimed to be a very well favoured district climatically for small-seed production, especially lucerne, and all four species of bumble bees occur there and, except *B. hortorum*, are very plentiful, a concentration of high efficiency pollinators awaits exploitation in that area.

Although the main object of the survey was to ascertain the species present and their distribution, other useful information has been obtained concurrently. It is obvious that numbers of individuals have a bearing on efficiency of pollination, and information on the life cycles of the bumble bees present is of importance in relation to time of controlled flowering of crops. Figures 1 and 2 give a picture of a typical life cycle and the observed population trends, respectively, of the four species in New Zealand.

It was found that, while *B. ruderatus*, *B. hortorum* and *B. subterraneus* behave in New Zealand much as they do in England, *B. terrestris* has responded to the milder winters here and undergoes only an incipient hibernation—sometimes whole nests over-winter. Nest founding is spread in time and so are the maxima of the various colonies. This has the effect of reducing the numbers of foraging individuals at any given time, and reduces the efficiency of this species as a pollinator. *B. terrestris*, however, is the commonest species and has the most populous nests.

Increasing Numbers of Individuals on the Wing

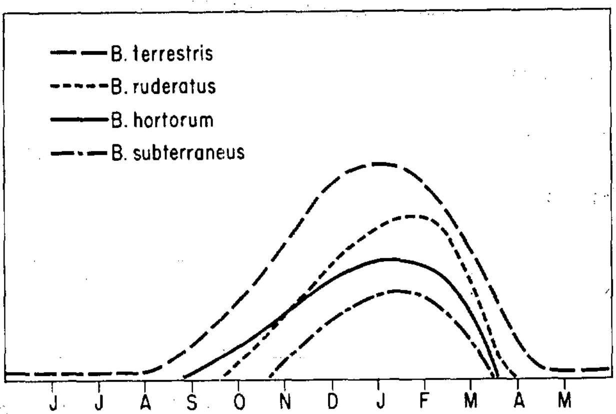

Fig. 2: Observed seasonal population trends in four species of bumble-bees.

Tongue length has a profound effect on foraging behaviour and governs to a large extent the type of flowers visited and manner of collection of nectar and pollen. Observations on foraging behaviour were made from time to time. *B. ruderatus, B. hortorum* and *B. subterraneus* are all long-tongued bees. They visit red clover always at the front of the floret and hence always brush against the sexual parts of the flower and effect pollination. *Bombus terrestris,* on the other hand, is short-tongued and when visiting red clover sometimes bites holes in the corolla tube close to the nectary, thereby obtaining nectar supplies without effecting pollination. This habit, although not resorted to by all nectar-gathering individuals and of course not by pollen gatherers of this species, has led to *B. terrestris* being condemned by growers as an unfortunate and undesirable introduction.

It must be remembered, however, that only some individuals acquire that habit and since *B. terrestris* is the most populous and ubiquitous species it must still account for a large proportion of pollination of red clover. In the case of lucerne, however, it is shown (Gurr, 1955) that the reverse situation pertains. *Bombus ruderatus,* a long-tongued bee, soon learns that, by alighting on the side of the flower and inserting its long tongue between the standard and wing petals, it can obtain the nectar without tripping the flower, thereby avoiding the explosive force of the released stigma on its body and the shower of released pollen. Honey-bees also soon learn to avoid the tripping mechanism of lucerne when they visit the flowers for nectar. In neither case, of course, is pollination effected as the sexual parts of the flower remain undisturbed. In February, 1954, at Omaka, in Marlborough, the writer observed *B. ruderatus* avoiding the tripping mechanism of lucerne, but *B. terrestris* invariably tripping the flower even when collecting nectar. It was pleasing to see confirmation of this observation in a paper (Brian, 1954) published later that year reporting similar findings by two groups of workers, one in Central Sweden and one in Denmark. Thus, although *B. ruderatus* is undoubtedly more efficient than *B. terrestris* as a pollinator of red clover, *B. terrestris* is the more useful species in the pollination of lucerne, because it trips more lucerne flowers than *B. ruderatus,* and so it is a more valuable species than was hitherto recognized.

High yields of lucerne seed do coincide with high populations of *B. terrestris,* and confirm these findings. Grassmere produces high yields of lucerne seed, and *B. terrestris* is the predominant species present, while Havelock-Okaramio, just 25 miles distant, is noted for its high yields of red clover, and here *B. ruderatus* dominates. Visits to these two districts were made between September, 1953, and November, 1954, and the population composition and foraging behaviour of the bumble-bees present were noted. It was found (Gurr, 1957a) that food supply can determine the population density of bumble-bees, and, moreover, can determine the species composition in a district by being available when one species and not when another first emerges from hibernation and at nest founding. Copious early spring food and dearth of late spring food favours *B. terrestris,* whereas the reverse favours *B. ruderatus.* Adequate food supply throughout the whole spring enables *B. ruderatus* to compete favourably with *B. terrestris* and sometimes to outnumber it; for example, in the Havelock-Okaramio district.

Cumber (1949) gives the first account of an overwintering nest of *Bombus terrestris* in New Zealand and he discusses the biology and ecology of bumble bees in relation to red clover seed yields in New Zealand (Cumber, 1953). He also studied the life cycles of *B. terrestris* and *B. ruderatus* for one year in the Levin-Foxton area (Cumber, 1954), and his findings were similar to those of the writer for the same species in the South Island.

Overseas much work has been done on the use of honey-bees for the pollination of these two crops and a diversity of results has been obtained. Bohart (1957) ably reviews them. Two papers have been published on work done is this country on their usefulness as pollinators of red clover. One concerned direction of honey-bees to red clover by feeding them an infusion of red clover blossoms in sugar solution in the hives at night so that the scouts would lead the nectar gatherers to that crop first thing next morning (Palmer-Jones and Smellie, 1950). It was shown that this technique was not practical on account of the technical difficulties of bee handling.

The other paper (Forster and Hadfield, 1958), dealt with bees found working a selected crop of red clover and the findings were that honey-bees comprised 77% of the effective pollinating insects in 1954, and 89% in 1955. However, it is the writer's opinion that these figures are too high as more account should have been taken of the relative efficiency as pollinators of honey-bees and bumble-bees. Their figures are based on the assumption that the two types of bees are equally efficient, whereas various overseas workers (Bohart, 1957) contend that bumble-bees pollinate between two and four times as many florets per minute as pollen-collecting honey-bees. From the writer's observations bumble-bees will continue to work under much more adverse conditions than honey-bees and thus their total time in the crop is greater than that of honey-bees.

The average seed yields of red clover, especially that of the late flowering Montgomeryshire strain, are much lower than in many overseas countries, although in favourable districts yields comparable with the best overseas yields are obtained. Best yields are obtained in countries in high latitudes, where during the clover flowering period there is almost continuous daylight. This allows pollinators to work almost 24 hours of the day. The long hard winters and short summers ensure that the population peaks of the different species are synchronous and coincide with the clover flowering period. Pollination efficiency in these circumstances is at its maximum. These conditions are most nearly approached in New Zealand in the Mackenzie country.

If bumble-bees are the main pollinators of these crops, district seed yields will depend on the suitability of the countryside for these insects and seasonal fluctuations of seed yield will coincide with good and bad seasons for them. More efficient land use, intensive cropping, and especially weed control in this country, tend to reduce the populations of bumble-bees, so unless they are purposely encouraged by providing them with food supplies and nesting sites, even lower seed yields can be expected.

We are now in a better position to consider the introduction of additional species of bumble-bees, but with our present knowledge of nesting requirements and food competition it is difficult to say whether fresh introductions will result in an over-all increase in bumble-bee numbers or simply an increase in species numbers. If importation of new species is contemplated, consideration should also be given to the Alkali Bee, *Nomia melandri,* a proved highly efficient pollinator of lucerne in the United States.

Although honey-bees alone proved to be ineffective as pollinators of red clover before the introduction of bumble-bees in 1885, under present-day conditions they have been shown to account for a percentage of the pollination of this crop. They have the great advantage that they can be transported from place to place and concentrated in a given area. With further study under our own conditions we should learn how and where they can be used as efficiently as they have been used overseas. With further study of the ecology of the species of bumble-bees present in New Zealand, we should learn how to increase their numbers and use them to the best advantage. Accurate local life-cycle data would enable better timing of the flowering period of the crop for bumble-bee pollination. Numbers could be increased by providing flowering plants that supplied food at times of dearth and nesting sites could be made available if these were shown to be a limiting factor.

This very brief account of the complex problem of pollination indicates that pollination is frequently the principal limiting factor in the growing of these crops for seed, and that the solution of the associated problems is the work of the entomologists. It must be understood, however, that the final seed yield is also the concern of the plant breeder, the agronomist, and the farmer.

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DISCUSSION

G. de la M. Nichols: *Would Mr. Gurr comment on the applicability to New Zealand conditions of Californian work which suggested that pollination of lucerne by honey-bees, "stocked" at a rate of 5 to 6 hives per acre, had increased seed production from 200 lb/acre to 1,000 lb/acre?*

A: With this use of honey-bees, best results were obtained with "open" stands of lucerne for they had twice as much nectar per flower, twice as many bees per flower, and twice as much seed per acre as dense stands (Bohart, 1957). Lucerne is generally grown in dense stands in New Zealand and may not therefore give such spectacular results. Several trials of this nature have been undertaken by the Apiary Division of the N.Z. Dept. of Agriculture—to my knowledge the results have not been published.

Q: *What is the size of a normal bumble-bee colony?*

A: This varies from species to species and from colony to colony. A populous colony of *B. terrestris* in New Zealand may contain between 400 and 500 individuals, other species considerably less.

Q: *If the Alkali Bee occurs in Australia, would there be any difficulty in importing it?*

A: If suitable arrangements could be made for its collection and dispatch, and authority obtained for its introduction into New Zealand, the task should not be difficult. Much more would have to be known about the species that occurs in Australia and its habits before introduction would be considered.

Q: *Do native bee species in Australia pollinate lucerne readily?*

A: According to Purdie (1961), some native bees pollinate lucerne but they are not widespread or numerous and their numbers vary from year to year. They are sensitive to temperature and do not work in cool weather. He advocates reliance on managed honey-bees to pollinate lucerne.

Q: *If some of the desirable bumble-bee species are present in too low numbers, would it be possible to breed them and liberate in specified areas?*

A: The cost of labour involved would be prohibitive even if it were possible to breed them in sufficient numbers to produce a significant increase in local numbers. If, however, more was known about the ecology of these species of bumble-bees, it might be possible to manipulate the environment in their favour and so increase their numbers.

Q: *Is there any hope of* B. terrestris *assuming large enough numbers to be effective as red clover pollinators under Canterbury conditions, particularly in view of its habit of coming out of hibernation in winter and suffering losses through changeable climatic conditions?*

A: Several authors, McBurney (1941), Dumbleton (1948), and Montgomery (1951), consider, as I do, that *B. terrestris* is by far the most numerous bumble-bee in Canterbury and that by virtue of numbers may well be the principal pollinator of red clover in this district. This, in spite of the undoubtedly undesirable habit mentioned by the questioner. In my opinion, the dearth of early spring food is the major limiting factor in the life cycle of *B. terrestris* in Canterbury, but availability of nest sites and maladjustment to climatic vagaries must contribute. The concentration of red clover crops in the Canterbury district is such that it may never be possible to achieve an adequate population of pollinators there to produce high seed yields.

Q: *What is the value of tree lucerne for providing early spring feed for bumble-bees?*

A: It is, in my opinion, the best early spring food supply available as it is in flower in most districts from late winter until September and bumble-bees are particularly attracted to it. Except that it is slightly frost tender when young, it can be grown almost anywhere. Because it flowers early, it tends to favour the early emerging species of bumble-bees, *B. terrestris*, and, where it occurs, *B. hortorum*. Lucerne seed growers would be well advised to grow tree lucerne in odd corners and around the homesteads to encourage *B. terrestris* which is the most efficient pollinator of lucerne in New Zealand.

Q: *What is the value of cruciferous flowers for providing early spring feed for bumble-bees?*

A: Since I have often taken specimens on these crops, they must therefore supply some food for bumble-bees during the flowering period.

Q: *What are the ecological factors which favour the predominance of* B. subterraneus *in the Mackenzie country?*

A: I can only make a guess, based on one observation made while collecting at Tekapo in late November. Both *B. terrestris* and *B. subterraneus* queens were working volunteer red clover when a sudden, cold, south-west change in the weather occurred; *B. subterraneus* continued to work long after *B. terrestris* had ceased. *Bombus subterraneus,* more tolerant of extremes of weather change, may thus be able to compete with *B. terrestris* in the harder conditions of this area while it cannot in the less harsh conditions elsewhere.

Q: *What are chief pollinators of white clover?*

A: Honey-bees.