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To cite this article: I. W. Forster & W. V. Hadfield (1958) Effectiveness of honey bees and bumble bees in the pollination of Montgomery red clover, New Zealand Journal of Agricultural Research, 1:5, 607-619, DOI: 10.1080/00288233.1958.10431568

To link to this article: https://doi.org/10.1080/00288233.1958.10431568

Published online: 15 Feb 2012.

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EFFECTIVENESS OF HONEY BEES AND BUMBLE BEES IN THE POLLINATION OF MONTGOMERY RED CLOVER

By I. W. FORSTER* and W. V. HADFIELD†

(Received for publication, 15 May, 1958)

Summary

In February 1954 and again in February 1955, 35 hives of honey bees were placed immediately adjacent to 10 acres of Montgomery red clover (Trifolium pratense) growing in an area considered to be favourable to bumble bees.

Insect activity was noted and it was computed that honey bees provided 77% of the effective pollinating insects in 1954 and 89% in 1955.

Spot checks made at several different points showed this to be a fair cross-section of insect activity on red-clover crops in South Canterbury.

INTRODUCTION

Two distinct strains of red clover (Trifolium pratense) are in common use in New Zealand: cowgrass or broad red clover and Montgomery red clover.

New Zealand supplies not only her own seed requirements of both clovers but, in most seasons, has a considerable surplus available for export. Montgomery red clover in particular has a ready demand overseas. While high seed yields are quite common from cowgrass, they are not usual in the case of Montgomery red clover, this crop being recognised as a shy seed setter (Hilgendorf). Under very favourable conditions, individual crops have yielded over 400 lb dressed seed per acre, but the average yield for New Zealand, over a 15-year period, is no more than 66 lb per acre. During that period the average annual yield varied from 32 to 155 lb per acre.

As red clover is practically self-sterile, it requires cross pollination before it can set seed. Being an entomophilous plant its flowers are

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designed for insect pollination and it is therefore dependent on insects for this service. Because it is not an open type of flower, the anthers and stigma are not readily accessible and it would seem that only those insects that continuously gather nectar and pollen, and have the necessary strength to spring the keel of the flower, are of any consequence as pollinators. This rules out the more or less casual visitors to flowers, such as flies and moths, and leaves only honey bees and bumble bees as worthwhile pollinators.

The natural affinity between bumble bees and red clover had long been apparent to observers. The history of agriculture in New Zealand had recorded spectacular increases in red clover seed yields with the introduction of bumble bees in 1839. However, from late in the last century concern had been regularly expressed at the decline in red-clover seed yields, which is reported to have significantly coincided with a marked decrease in the bumble-bee population (Canterbury Agricultural College 1954; Thomson 1922) despite further bumble-bee importations in 1906. There are no definite records, however, to show that this reduction in seed yields and lessening of bumble bees has actually been the steady pattern of events (Gurr, unpublished report).

Honey bees have long been recognised as superior to other insects in the general field of pollination. The permanency of the colony not only allows honey bees to be present in large numbers at any time of the year, but also requires that they seriously and diligently visit flowers for nectar and pollen. Honey bees make full use of their field force as their working methods are highly organised. Though not completely domesticated, they can be concentrated at any particular point as required, because they are amenable to control.

The oft repeated factual assertion that red-clover florets are about 10 mm deep and that the tongue of the honey bee is never more than 7 mm in length, has created a large body of opinion that honey bees cannot work red-clover flowers. This conclusion is unfounded because it is the whole proboscis that is inserted into the flower and, therefore, the reach of the tongue is governed by the distance this organ can be protruded and the amount of thrust that the bee can impart. Obviously actual tongue length does not provide the complete answer (Snodgrass 1925). Also the activities of pollen-gathering honey bees have been largely overlooked, and the fact that the distance down to any nectar would be less than 10 mm according to the quantity present.

Methods used by workers overseas to direct honey bees on to red clover by feeding hives with syrup infused with the aroma of red-clover flowers were applied in New Zealand (Palmer-Jones and Smellie 1950). However, so much skill and labour is necessary for the successful operation of the method that the authors decided that it is doubtful if its practical application has much future in New Zealand.

Casual observations had made it plain that many short-tongued bumble bees (Bombus terrestris) adopted the habit of biting through the side of the florets. Although it has been stated that any floret cut at the base in this manner fails to set seed (Canterbury Agricultural College 1954), it is not clear whether it has been proved to what extent
such mutilation affects the capacity of the floret to set seed if it has been previously, or is subsequently, pollinated. Obviously the bumble bee piercing the sides of the florets must fail to achieve pollination, and any work done would need to assess to what extent this factor reduces the effectiveness of bumble bees as pollinators.

Observations made from time to time by one of us (I.W.F.) had established the fact that honey bees were regular visitors to red-clover crops in New Zealand. Although red clover is not a dependable source of nectar, red-clover honey has been regularly identified in bee hives and large amounts of red-clover pollen are common. The important role of the honey bee as a pollinator of red clover in other countries was fast receiving recognition and it was considered desirable that some steps should be taken to define the position in New Zealand. The Extension Division, Department of Agriculture, Timaru, had already selected an area for investigations into red-clover seed production and the opportunity was therefore taken to record some aspects of insect activity on this crop. Although it was realised that observations would be intermittent because time was limited, it was felt that much valuable information could be obtained.

**EXPERIMENTAL AREA**

The experimental area was on the farm of Mr. S. A. Marshall at Taiko, situated approximately 9 miles from Timaru. The countryside is of a rolling formation, dropping sharply for nearly 400 ft into the wide fertile Taiko Valley about half a mile west of the crop under observation. The soil is described as a Claremont silt loam. The district is mainly good clean pasture with a fair amount of cropping and some small-seeds production. Gorse grows in the vicinity in hedges, on roadsides, and in shallow gullies. Several home gardens in the locality contain the usual range of nectar- and pollen-producing plants.

The vast escarpment that forms the eastern side of the Taiko Valley carries considerable growth of mixed vegetation comprising gorse (*Ulex europaeus*), broom (*Sarothamnus scoparius*), cabbage tree (*Cordyline australis*), lawyer (*Rubus*), matagouri (*Discaria toumatou*), five-finger Jack (*Nothofagus arborescens*), kowhai (*Edwardsia micropyllyla*), koromiko (*Hebe salicifolia*), mahoe (*Melicytis macrophylla*), broadleaf (*Griselinia littoralis*), putaputawheta (*Carpodetus serratus*), mullein (*Verbascum thapsus*), and tussock.

The area was considered ideal for bumble bees. The terrain and flora offered ample cover for hibernating queens, also nesting places and a reasonable continuity of nectar and pollen supplies.

The crop of Montgomery red clover, about 10 acres in extent, had been sown down in the autumn of 1953. Growth was even and carried abundant bloom during both the 1954 and 1955 flowering season. In all respects the crop appeared an ideal one for seed production.

Thirty-five hives of bees were placed on the edges of the crop when the red clover was just starting to flower. The hives were of medium strength in 1954 and of full strength in 1955.
Owing to the dry conditions in 1954 no other flowers of any consequence were blooming within bee range to compete with the red clover for the attention of insects. In 1955, thistles and a sparse brassica crop were being visited by honey bees and some scattered white clover by both honey bees and Bombus terrestris.

**Experimental Procedure**

*Weather Observations*

Air temperatures were recorded. Relative humidity was taken with a wet and dry bulb. In 1954 soil temperatures were taken in a hollow and on a ridge. General climatic conditions were noted.

*Counts of Bees on Crop*

An attempt was made to obtain counts by the method of sweeping with a net used by Palmer-Jones *et al.* (1954), but as it was necessary to record working habits as well as insect species and density, this was abandoned in favour of counting over a set area. A strip 4 ft × 5½ ch was measured out across a representative portion of the field giving an area of 1/30 acre. Counts were obtained by walking slowly down this track and then multiplying the result by 30 to give the number of bees per acre.

It was expected to find all three of the species of bumble bee that had at that time been definitely identified as being present in New Zealand, i.e., *Bombus terrestris*, *B. ruderatus* and *B. subterraneus* subsp. *latreillellus* (Dumbleton 1948). Because *B. ruderatus* and *B. subterraneus* are difficult to differentiate with any certainty under field conditions, and because both have long tongues and are of similar habits, they were grouped together under the name of *B. ruderatus* type.

*Additional Counts*

In order to obtain a cross section of insect activity over the South Canterbury district, spot counts were made on red-clover crops as opportunity offered during February 1955. Small apiaries had been moved on to some of these crops for pollinating purposes and the average concentration of bee hives would be a little above normal for the district but nowhere near that of the trial crop. On these occasions it was not convenient to work out an area before commencing to count, so a 4-ft stick was used as a guide. Counts were made along this strip for a distance of approximately 5½ ch. The operator then retraced his steps and using the 4-ft stick as a unit, measured the exact length of the strip over which the count had been made. From the figures obtained the density of bees per acre was computed.

*Seed Yields*

It was planned to use a system designed to compute the actual amount of seed produced per acre. The proposed method was to work out the number of flower heads per acre by making random counts within a wire gauge, 1 ft square. The number of seeds from 100 flower heads picked at random would complete the information
required to calculate the total amount of seed in the crop. It was considered desirable to have this theoretical yield as a check on the actual amount of seed obtained by the farmer because it is recognised that a certain amount of seed is lost in the ordinary process of harvesting. This wastage could be a variable factor according to weather, condition of crop and the efficiency of the equipment used.

However, as time was not available to carry out this detailed work the actual quantity of seed harvested was taken as the measure of the performance of each crop, these figures being considered reasonably reliable for the purpose of comparison. Also in a trial of this nature it is very difficult to establish a satisfactory standard for comparison of yields. The only convenient check was a comparison with crops throughout the district, none of which had hives of bees placed on them at anywhere near the concentration that existed on the trial crop.

Results

Counts of Bees on Crops

Honey bees and both long- and short-tongued bumble bees were usually present on the crops although no B. ruderatus type were recorded in those counts made in January 1955.

In 1954 the average number of honey bees per acre on the trial crop at Taiko was 1392, pollinating bumble bees 414, and non-pollinating bumble bees (i.e. bumble bees biting the sides of the florets), 765.

In 1955, the figures for the trial crop were: honey bees 1505, pollinating bumble bees 180, and non-pollinating bumble bees (i.e. bumble bees biting the sides of the florets), 54, while the spot counts on various red-clover crops gave average per-acre densities of 1146 honey bees, 162 pollinating bumble bees, and 86 non-pollinating bumble bees.

Even under optimum conditions, bee counts, including both honey bees and bumble bees, did not quite reach one bee to the square yard. In making bee counts the number of each species working the sides of the florets was recorded, as this information is of utmost importance in weighing their worth as pollinators.

Honey-bee counts showed a greater diurnal variation than did bumble-bee counts (Tables 1 and 2 and Fig. 1), tending to build up during the morning and decrease during the afternoon. Honey bees also showed a greater response to temperature. At 60°F honey-bee activity decreased sharply and in the spot counts, full particulars of which are not shown in table form here, honey-bee activity ceased at 59°F while bumble bees continued working, although mainly in sheltered corners and at a slower rate. The complete absence of bumble bees at 5 p.m. on 7 February 1955, compared with the relatively high honey-bee count, cannot be explained.

In Fig. 2, "effective bumble bees" are those of all species working the tops of the flowers and thus achieving pollination, while "non-effective bumble bees" are the B. terrestris biting holes in the sides of the florets and so failing to pollinate. It will be noted in Fig. 2 that
<table>
<thead>
<tr>
<th>Feb. 1954</th>
<th>Weather Conditions, Insect Counts Per Acre and General Information, 1954</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>2 p.m. Sunny, light easterly breeze</td>
</tr>
<tr>
<td>9</td>
<td>4 p.m. Sunny, calm</td>
</tr>
<tr>
<td>10</td>
<td>2 p.m. Hot, sunshine, calm</td>
</tr>
<tr>
<td>10</td>
<td>4 p.m. Warm sunshine, calm</td>
</tr>
<tr>
<td>11</td>
<td>9 a.m. Warm, cloudy, N.W. breeze</td>
</tr>
<tr>
<td>11</td>
<td>11 a.m. Warm, cloudy, N.W. breeze</td>
</tr>
<tr>
<td>12</td>
<td>9 a.m. Fine, calm. Light cloud</td>
</tr>
<tr>
<td>12</td>
<td>11 a.m. Light easterly breeze</td>
</tr>
<tr>
<td>15</td>
<td>2.30 p.m. Warm, some cloud. Has been raining</td>
</tr>
<tr>
<td>18</td>
<td>4 p.m. Misty rain.</td>
</tr>
<tr>
<td>------</td>
<td>---------</td>
</tr>
<tr>
<td>Feb. 1955</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>5 p.m. Cold, S.E. wind</td>
</tr>
<tr>
<td>8</td>
<td>noon Cloudy. Has been raining</td>
</tr>
<tr>
<td>9</td>
<td>noon Has been raining</td>
</tr>
<tr>
<td>10</td>
<td>9 a.m. Fine, Sunny. Very light E. breeze</td>
</tr>
<tr>
<td>10</td>
<td>10 a.m. Fine, Sunny. Very light E. breeze</td>
</tr>
<tr>
<td>10</td>
<td>11 a.m. Fine, Sunny, Calm</td>
</tr>
<tr>
<td>10</td>
<td>noon Fine, Sunny, Calm</td>
</tr>
<tr>
<td>10</td>
<td>2 p.m. Fine, Sunny. Freshening E. wind</td>
</tr>
<tr>
<td>10</td>
<td>3 p.m. Fine, Sunny. Very light E. wind</td>
</tr>
<tr>
<td>10</td>
<td>4 p.m. Fine, Sunny. Light E. breeze</td>
</tr>
<tr>
<td>10</td>
<td>5 p.m. Fine, Sunny. Light E. breeze</td>
</tr>
</tbody>
</table>
bumble bees were more numerous in 1954 than in 1955 but the pollination value of the greater concentration in 1954 was largely offset by the greater percentage working through the sides of the florets. *B. ruderatus* type did supply a slightly higher percentage of pollinators than *B. terrestris* in 1954 (Table 3) but only half as many in 1955, while on the spot counts the species were about equal. Table 3, while separating those insects working the sides of the florets from the effective

![Fig. 1.—Counts of honey bee and bumble bee pollinators.](image1)

![Fig. 2.—Average daily counts of pollinating bumble bees and non-pollinating bumble bees.](image2)
pollinators, does include all insects. This means that the large number of *B. terrestris* working the sides of the florets in 1954 gives a high total count, and thus the 53.9% of honey bees, as shown in Table 3, is no indication of the proportion of pollination performed by them. The vital comparison is graphically depicted in Fig. 1 which summarises the relative number of pollinators supplied by honey bees as compared with bumble bees.

### TABLE 3. Percentages of Insects of Various Species and Working Habits

<table>
<thead>
<tr>
<th>Year</th>
<th>Location</th>
<th><em>B. terr.</em> Working Florets from Top (%)</th>
<th><em>B. terr.</em> Working Florets from Side (%)</th>
<th><em>B. rud.</em> and <em>sub. lat.</em> Florets Working from Top (%)</th>
<th>Honey Bees Florets Working from Side (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1954</td>
<td>Trial area at Taiko</td>
<td>7.7%</td>
<td>29.7%</td>
<td>8%</td>
<td>53.9%</td>
</tr>
<tr>
<td>1955</td>
<td>Trial area at Taiko</td>
<td>6.5%</td>
<td>3.1%</td>
<td>3.7%</td>
<td>86.5%</td>
</tr>
<tr>
<td>1955</td>
<td>Spot counts over various crops</td>
<td>5.8%</td>
<td>6.3%</td>
<td>5.7%</td>
<td>82.2%</td>
</tr>
</tbody>
</table>

**Bee Behaviour**

Honey bees and bumble bees working from the tops of the florets were gathering pollen. Very little nectar was being gathered by honey bees as the honey sacs of the many bees examined were nearly empty. This was also borne out by examination of the experimental hives which showed that red-cover pollen was being stored but no new nectar was being brought in.

On the trial plot at Taiko, *B. ruderatus* were confined mainly to the end of the counting strip nearest to the gorse hedge and on the spot counts showed a noticeable preference for sheltered locations.

While the two honey bees working the holes bitten by the *B. terrestris* (Table 3), made a rambling approach to the flower, the *B. terrestris* themselves were quite consistent in their working methods. Those working the sides of the florets went straight to that part of the flower and the others went straight to the top.

**Speed of Working**

An assessment was made of the speed of working of the different species of bee by counting the number of florets visited per minute. While honey bees worked at a fairly consistent rate, varying only between 20 and 16 florets per minute, bumble bees were not so consistent and visits varied from 31 florets per minute to complete in-
activity when rain or low temperatures had reduced the bumble bees to a state of immobility. No attempt was made to decide at what stage of low activity bumble bees should be discounted and the counts shown include all bumble bees present on the crop.

While any assessment of the overall working speeds of honey bees as opposed to bumble bees must be an arbitrary one, it would appear that on the counts as made, each species should be credited with a like average speed of working.

Sugar Content of Nectar

An endeavour was made to record the sugar content of the red-clover nectar by removing the honey sacs of bees caught on the crop and placing the contents on the prism of a pocket refractometer graded to give sucrose as a percentage. However, nectar loads were so small that the contents of from 6 to 12 honey sacs were required to give a reading, and as the material thus tested was probably honey brought from the hive the results cannot be taken as having any significance.

Soil Temperatures

No significant relationship was apparent between soil temperatures and insect activity.

Seed Yields

In 1954, 240 lb of machine-dressed seed per acre was harvested from the trial crop at Taiko. Although this was double the average for the district, taken over approximately 80 crops, it was exceeded by the yield from eight other crops which produced from 243 to 400 lb per acre.

The harvest from the trial crop in 1955 was 274 lb of machine-dressed seed per acre, being exceeded by 12 other crops in the district with yields of from 277 to 480 lb per acre. The seed yields from the Taiko crop were the highest the farmer had ever experienced.

Discussion

Although observations were not continuous, the insect activity and results recorded at Taiko over the two red-clover flowering seasons, together with the spot checks on other red-clover crops, give a fair cross-section of conditions throughout South Canterbury.

A very significant feature of the trials was the large number of *B. terrestris* biting holes in the sides of the florets and so greatly reducing the value of the bumble-bee population. However, *B. terrestris* actually provided a greater number of effective pollinators than did the *B. ruderatus* type, and, providing the mutilation of the flowers by side-biting individuals does not directly affect the flowers’ ability to set seed, *B. terrestris* appears to be of at least equal importance to *B. ruderatus* in the pollination of Montgomery red clover. Only two honey bees were observed working through holes bitten by the bumble bees and even they did not act as though confirmed in this habit.
Practically the entire field force of honey bees may thus be regarded as effective pollinators. The smaller number of bumble bees in 1955 could have been the result of various undetermined factors. The only recorded condition which may have caused this fluctuation was the greater amount of competing flora present in 1955, which by dispersing the relatively small bumble-bee population, would reduce the number present on any particular area. Honey bees, on the other hand, would be numerous enough to saturate the competing sources without reducing the numbers on any particular crop. It is interesting to note (Fig. 2) that, except for the high count on 10 February 1954, the effective bumble bee population remained fairly constant. Any increase in bumble-bee numbers seemed to be within the non-effective "robbing" group. This could mean that it is greater competition for nectar that drives *B. terrestris* to bite the sides of the florets. This competition would be mainly between bumble bees, as honey bees in this trial gathered mainly pollen and therefore did not affect the supply of nectar in the flowers. *B. terrestris* biting the sides of the florets gather no pollen and so nectar must be the only attraction to them. It was noticeable that both honey bees and *B. terrestris* working the tops of the florets, because of their shorter tongues, had to force the keel of the flower much further apart to reach into it than did *B. ruderatus*. For this reason they may be more deliberate pollinators.

In assessing the number of effective pollinating insects, it is necessary to discount those that work the sides of the floret. On this basis we find that honey bees provided 76% of the pollinators at Taiko in 1954, 89% at Taiko in 1955, and 87% over scattered crops in 1955. The close agreement of these figures supports the contention that this is a fair indication of the worth of honey bees in red-clover pollination. Although 1954 and 1955 were excellent for the production of red clover, the yields of 240 and 274 lb per acre on the trial area can be considered quite satisfactory, even when compared with the high district average of 120 lb per acre in 1954. It is also interesting to consider that Sweden which is often held up as the ideal for red-clover seed production, produced an average of 251 lb per acre during the 10-year period 1921-31 (Canterbury Agricultural College 1954). As this Swedish average probably includes "cowgrass" types which set seed much more freely, the figure could be considerably higher than the yields for comparable late-flowering types.

In the absence of observations made during the flowering season, it is not possible to determine just what factors operated in favour of those South-Canterbury crops that produced yields in excess of the Taiko trial plot. The entire district is fairly heavily stocked with apiaries, so those crops could easily have as heavy a concentration of honey bees as the trial area. It is interesting to note that the average number of honey bees per acre working the trial crop with its heavy concentration of bee hives was only 15% more than that of the bees working the various crops where hive concentration was comparatively light. In fact the maximum count on the trial area of less than one
bee per square yard appeared to be only a fraction of that which the hives on the crop were capable of supplying.

Although it was not possible to record a definite comparison, the honey-bee field force in 1955 did appear to work the red clover more keenly than in 1954, despite some competition from other flora that did not exist in the previous year. This could be the result of the stronger condition of the colonies placed on the crop in 1955. The increased amount of seed produced in 1955 could well be a reflection of this circumstance when it is considered that normally the yield tends to decrease in the second consecutive year of harvesting for seed.

In 1955, when the hives were all at one end of the crop, an endeavour was made to ascertain the effect on seed yield of proximity to the hives. Seed was harvested separately from 10 plots, each 1-yard square, situated at intervals of 1 chain from the apiary. The figures obtained showed no significant trend. The only variation was that caused by differences in the growth of the crop.

Conclusions

South Canterbury is a district where conditions are favourable for bumble bees yet these studies would indicate that honey bees play the major part in pollinating red clover, and the maintenance of a dependable honey-bee population is definitely in the interests of red-clover seed growers.

It is essential to have honey-bee colonies at full strength for pollination purposes.

The effectiveness of the available bumble-bee population is greatly reduced by the large numbers of *B. terrestris* that bite through the sides of the florets. In spite of the side-biting habit of some individuals, *B. terrestris* is probably of equal value to *B. ruderatus* as a pollinator of red clover because of its superior numbers.

While the deliberate stocking of crops at a rate of 3½ hives of honey bees per acre did not give outstandingly high seed yields, these were well above average and compared favourably with those reported from other countries. As seed set did not decrease at distances up to 10 chains from the hive, it would appear that scattering the hives through the crop is not necessary in the case of small or moderate sized fields.

Further work is necessary to decide to what extent crops can be beneficially and economically stocked with honey bees.

Acknowledgements

Thanks are due to Mr. S. A. Marshall for his co-operation in making his crop available for this experiment and to Davidsons' Apiaries, Timaru, for the hire of bees and the placing of them where and when required.

References


