Eva Crane Trust

ECTD_004

TITLE: Water and the honeybee colony

SOURCE: Lecture for Central Association of the British Beekeepers

DATE: 1949

(4) (1949) F

CENTRAL ASSOCIATION

OF THE

BRITISH BEE-KEEPERS'

ASSOCIATION

LECTURE

Water and the honeybee colony

By E. E. CRANE

November 26th 1949

Copies of all Lectures given to the Central Association may be obtained from

Hon. S. ROAD,

Hon. Secretary and Treasurer:
Mrs. M. E. HORTON.
8, GLOUCESTER GARDENS,
ILFORD ESSEX.
Tel.: VALentine 1243

Water and the honeybee colony

By

E. E. CRANE

In this lecture I want to draw your attention to the importance of water to the colony as a unit; I shall not have time to discuss in addition problems concerning the individual bees and water: the behaviour of bees foraging for water, their choice of a water supply, and so on. We know comparatively little about the physiology and psychology of the colony, and a considerable part of what I have to say will not be "text-book" knowledge; I want to show you some of the problems which need elucidation, and to make suggestions as to what *may* take place in the hive, hoping that some of you will be encouraged to think about these things and to observe your own bees with them in mind.

I propose to divide the subject into three parts, and to consider the relationship between water and the honeybee colony in three seasons of the year which correspond roughly to summer, winter and spring. In each of these seasons the colony's water problem shows one pre-eminent characteristic. In summer, it is the disposal of surplus water from nectar; in winter, when the colony is clustered, it is the disposal of water produced by the consumption of honey; finally in spring, during the brood-rearing period before nectar is being brought into the hive in appreciable quantities, it is the collection of water, necessitated by the peculiar conditions of the colony at that time. It is perhaps the most interesting period of all from the present point of view.

SUMMER: THE SEASON OF NECTAR COLLECTION

Most of the nectar which the bees collect and bring into the hive contains much more water than the honey which they make from the nectar; and the disposal of the surplus water is an operation which can be carried out only by the colony—it is beyond the power of the individual bee.

It must be constantly borne in mind that the amount of honey produced from nectar is not only the "surplus" you take from the hive; the amount used for rearing brood and for maintaining the colony is at least several times as great as the "surplus" taken at the end of the season.

We do not know exactly the weight of nectar of a given sugar concentration which is used by a colony in the production of 1 lb. honey, and this weight certainly varies according to conditions. But we can make estimates of the weight according to various simple assumptions. Fig. 1 gives some such estimates, and it shows how the weight of nectar used to produce 1 lb. honey varies with the sugar concentration of the nectar collected. No account is taken of any chemical changes which may require energy, and the following assumptions have also been made in obtaining the three curves:

(*a*) that the honey produced contains 80% sugar and 20% water; this is roughly, but not exactly, true.

(*b*) in curve (1) - - - - - - - - -, that the bees need do no work in order to evaporate the surplus water.

(*c*) in curve (2) ————————, that all the work of evaporation is done by the bees, and that all the energy required for this work is obtained from *nectar*.

(*d*) in curve (3) . . . ., that all the work of evaporation is done by the bees, but that all the energy required for this work is obtained from the *honey*.

In curve (1), 1 lb. honey is obtained from 1 lb. 80% nectar, from 2 lb. 40%, 4 lb. 20% nectar, and so on. In curve (2), 1 lb. honey is still obtained from 1 lb. 80% nectar, since no evaporation is required, but it requires rather more than 2 lb. 40% nectar and over 6 lb. 20% nectar, to produce 1 lb. honey. The extra nectar is consumed by the bees in order to provide the energy necessary to evaporate the 1 lb. or 3 lb. water. Curve (2) separates more and more from curve (1) as the sugar concentration of the nectar decreases. Finally, in curve (3) the amount of nectar of any given

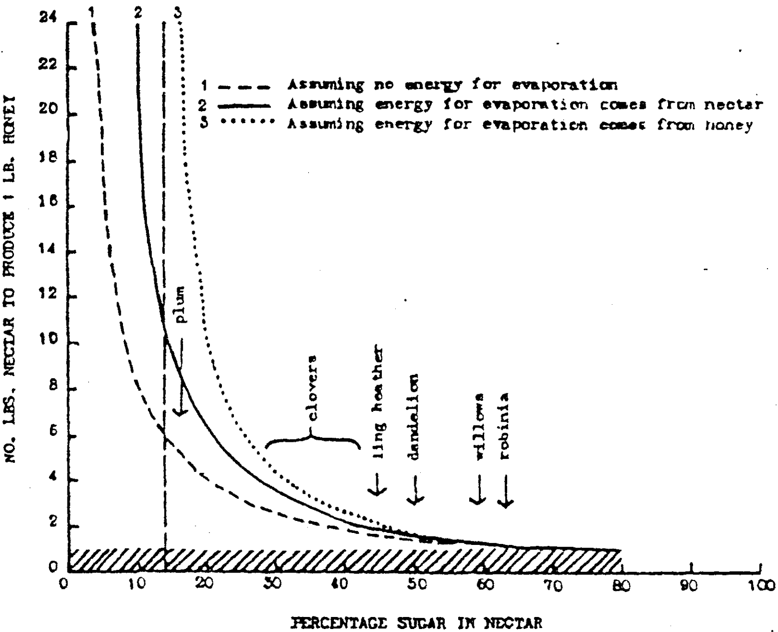

Fig. 1. Variation of the weight of nectar required to produce 1 lb. honey with the sugar concentration of the nectar.

concentration used to produce 1 lb. honey is even greater than in curve (2), because extra work has been done in concentrating the " energy-producing " nectar. This curve rises so steeply as the sugar concentration of the nectar decreases, that at 13% an *infinite* amount of nectar would be needed to produce 1 lb. honey. On the assumptions made, it is not worth the bees' while to collect nectar containing 13% sugar or less—they get no net return of honey from it.

It seems to me likely that the curves representing the true state of affairs under different conditions during the summer lie between curves (1) and (2), or possibly under certain adverse conditions in badly ventilated hives, rather above curve (2). The practical lesson to be learned is how much more important the work of evaporation becomes as the concentration of sugar in the nectar decreases and, as will be shown shortly, how important suitable hive conditions are in minimizing the amount of honey or nectar which is " lost " to the colony (or to the beekeeper) because it is used to provide the energy necessary to convert nectar into honey.

Before we pass on to this aspect of the problem, it is worth comparing the sugar concentrations of the nectars of some important bee plants. It is well known that the percentage of sugar in nectar secreted by one species varies according to the variety, the soil, and so on, and that the composition of nectar from even a single plant varies according to the time of day and the weather (especially the atmospheric humidity). Single figures given can therefore be no more than rough guides. Vansell (1942) in America and Beutler (1949) in Germany have both measured the percentage of sugar in nectars from specimens of many plants, and a few results are given in Fig. 1. It is clear from these that if plum and dandelion are accessible to a colony of bees at the same time, it is much more profitable for the bees to collect nectar from dandelions than from plums—according to Fig. 1 they have to dispose of less than a pound of water for every pound of dandelion honey they produce, but over four pounds of water (and possibly over twice this amount) for every pound of plum honey. In addition to this, the number of foraging journeys necessary for the collection of nectar for 1 lb. honey is about three times as many if they use plum instead of dandelion nectar. The fact that bees work dandelions for nectar in preference to plum blossom is therefore understandable. There is, however, another aspect of this problem, which I shall discuss towards the end of this lecture.

We must now return to the question : how much of the energy required for evaporating the water from nectar is provided by the bees ? Every pound of water evaporated at hive temperatures requires the expenditure of about 260 Calories. Each pound of honey consumed provides about 1300 Calories, sufficient energy to evaporate about 5 lb. water. Looking at it another way, a colony which produces a total of 350 lb. honey in the season from nectars with an average sugar content of 35% (a reasonable figure) must evaporate 450 lb. water, which could be done by consuming an *extra* 90 lb. honey. The whole of this amount would, however, not normally be needed, because the bees can utilize energy available from air currents.

Hazelhoff (1942) measured the rate of flow of air through a hive (similar to a W.B.C. hive with a single brood chamber) in the summer under various conditions. He sealed up all joints and left open only the entrance, and the feed-hole in the crownboard through which the air left the hive ; this air was measured and subsequently analysed. When the colony in the hive was quiet, with no bees fanning at the entrance, about a tenth of a litre of air passed through the hive every second : the air in the brood box was changed about once in five minutes. But when only *six bees* were fanning at the entrance, the rate of flow of air through the hive was increased above five times : the air in the brood box was changed every minute. This result suggests that fanning produces a current of air which (unless saturated with water vapour) can evaporate surplus water and remove it from the hive at a very small expenditure of energy on the part of the colony as a whole. Experimental results are lacking for the rate of flow of air through a hive during the night at the time of a nectar flow, but we know that there *is* a strong current of air.

The bees can use this method for disposing of surplus water economically only if the ventilation of the hive is such that they can maintain a strong through draught. In a badly ventilated hive, or possibly in a hive in a very shut-in position, it seems likely that the bees must expend a much higher fraction of the energy of evaporation. The micro-climate in which a hive is situated may be more important than we know ; it is exceedingly difficult to obtain quantitative information about its effects, although Dugat (1950) has published some results. It is a subject which at present forms part of the art rather than the science of beekeeping.

When bees are fed concentrated sugar syrup in autumn, water has to be evaporated from it, but the outside temperature is then considerably lower than during most nectar flows. In Canada, Gooderham (1938) weighed colonies before and after feeding syrup of various concentrations in early October, in order to find what percentage was stored by the bees. He repeated his experiments in three successive years, and one can calculate from his results that the sugar " lost " during feeding was very nearly equal to that necessary to provide the energy for the physical work of evaporating the water (260 Calories per lb.) from the various concentrations of syrup used. It seems likely that, in this case at least, the bees provided the whole of the energy required for evaporation.

WINTER: THE SEASON OF CLUSTERING

When the last nectar flow is over, and breeding has finished for the year, the colony's water problem becomes in some ways simpler, because there is much less surplus water to be disposed of; on the other hand the conditions for survival of the colony are far more stringent in winter than in summer and, as has so often been pointed out, dampness is a greater winter enemy of the colony than cold.

Although the bees are not breeding, the consumption of a certain amount of food is necessary to provide the energy for the maintenance of a non-lethal temperature at all, or most, points of the clustered colony. The honey consumption during the whole non-breeding period is likely to be only a few pounds. For every pound of honey (80% sugar) consumed, 0·85 lb. oxygen from the air is used up, and the bees gain energy (1300 Calories), carbon dioxide and water:

$$\underbrace{\text{1 lb. honey}}_{\text{0·8 lb. sugar + 0·2 lb. water}} \quad + \quad \text{0·85 lb. oxygen}$$

$$\xrightarrow[\text{1300 Calories}]{\text{energy released}} \quad \text{1·17 lb. carbon dioxide + 0·68 lb. water.}$$

The last two products—in fact the whole of the *chemical* products of metabolism—are " waste " and must be disposed of if the colony is to remain healthy. A honey consumption of 5 lb. gives the bees about 3½ lb. water to dispose of, at a time when their actions are extremely restricted. Every mouldy comb found in a hive in spring testifies to the fact that in that hive the surplus water was *not* satisfactorily disposed of, but condensed in the colder parts of the hive. The benefit of adequate winter ventilation in hives has been brought before beekeepers many times in the past few years, and I will not dwell on it further. Ventilation in very heavily insulated hives, designed to have an internal volume little more than that of the cluster, is a different problem, which there is no time to discuss now.

SPRING: THE SEASON OF BROOD REARING WITHOUT A NECTAR FLOW

You will all realize that the whole of the spring—up to say the beginning of fruit blossom in April—is not characterized by the absence of nectar; and in so far as any district provides an earlier nectar flow, the following remarks must be modified when applied to it.

I want to suggest that with the onset of a substantial rate of breeding the whole position is changed, and that it is changed not only in quantity but *reversed*—the dangerous winter water surplus becomes a deficit, which can be made good only by the expenditure of energy (and therefore of honey) by the bees.

In the spring of 1948 the B.B.K.A. Research Committee conducted experiments on the effect of feeding syrup to colonies in spring. The results of these experiments suggested that while colonies with easy access to water outside the hive gained little or nothing from the spring feeding of syrup, those whose water foragers collected water some distance from the hive (say over 50 yards) *did* gain. This was interpreted as indicating that the water, and not the sugar, in the syrup might be the beneficial part of it, and the experiment was repeated in the spring of 1949 in an extended form designed to test this point.

Beekeepers taking part in the experiment set aside in the autumn of 1948 a group of four colonies, matched as far as possible with respect to strength, winter stores, strain of bees, and age of queen. In February 1949, each group was reported on (for disease, signs of queenlessness, etc.), and the beekeeper was instructed to use three of the four colonies for the experiment proper; (the purpose of the original use of four colonies was to provide one "reserve" colony). The beekeeper was further instructed to feed a specified colony (S) with syrup—1 lb. sugar dissolved in 1 pint water per week from early March to (roughly) the end of April; to feed a second specified colony (W) with water over the same period; and to leave the remaining colony (C) unfed, to serve as a control. Water was to be provided for colony W in excess of requirements, in a bottle or perforated tin feeder. The weight taken each week, of syrup by colony S, and of water by colony W, was measured and recorded.

The details of this experiment will be published in full elsewhere; the average results were briefly as follows:

(1) small colonies fed syrup developed more rapidly than their control colonies;

(2) large colonies fed syrup did not develop at a different rate from their control colonies;

(3) small colonies fed water developed as rapidly as those fed syrup, and more rapidly than their control colonies;

(4) large colonies fed water did not develop more rapidly than their control colonies.

Results (1) and (2) confirmed results of the 1948 experiment.

The amount of water taken varied considerably from colony to colony; on the average it increased steadily from about 2 oz./week in early March to about 12 oz./week in late April: a total of about 60 oz./colony.

It is commonly known that bees fetch water in spring in fairly large quantities, and that they do so because they are rearing brood. The results quoted above confirm the suggestion that the water is of greater value to the colony than the sugar, providing that the colony already has adequate stores (as these experimental colonies had). The results also suggest that some of the energy (and therefore honey) used by the bees in fetching water could be saved if the beekeeper supplies water inside the hive in such a way that the bees will take it; experience shows that the point of access to the water must be very close to the brood nest.

Even when water is provided in a suitable feeder in the hive, and the bees are using it, they are observed to fetch water from sources outside the hive. Various determinations have been made of the rates at which water is carried into a hive in spring when none has been supplied inside; some results are given in Table 1. While these results depend on the rate of brood rearing in the individual colonies, the rates at which water was fetched are all several times as great as the average rate at which water was taken from within the hive for any period in March or April in the experiment in this country described earlier. Ratz (1929), who fed water in a side wall of each of five hives, found that the weight of water taken per colony per day increased from 2¼ oz. in early April to 12 oz. at the end of June (18-85 oz. per week).

It seems that, for some reason which I confess I do not know, bees prefer to fetch at least part of their water supply from sources outside the hive. Lieutenant Colonel E. C. Brown (1950), who has been making daily

TABLE 1

Consumption of water by honeybee colonies in spring (various observers)

Author	*Period*	*No. colonies observed*	*Average wt. of water taken per colony per day (oz.)*	*Equivalent rate in oz. per week*
Gendot (1907)	April, 1905	12	6	43
Fasold (1911)	21 April-10 May, 1911	3	8	58
Pickel (1911)	16 April-26 May, 1911	2	6	40
Park (1946)	May, 1920	3	10*	70*

*The colonies had been confined for the previous day.

observations on the water-foraging habits of bees throughout the year, writes of a day in mid-April, " To-day bees flew through rain (at 48°F. shade temperature) to get water, and they went into the (water) feeders as well. On other days recently they have crowded the fountains and the fruit blossom, and have neglected the feeders where the water temperature varied from 60°-73°F."

An inefficiency which seems to be inherent in the economy of the honeybee colony is the need to use energy in the summer and autumn, to *remove* water from nectar so that the resultant honey will not ferment during the winter and spring, and the consequent need to use additional energy to *fetch* water in the spring when brood rearing has begun. Bees cannot store water with their honey, because this would then ferment ; but neither can they store it separately, except for short periods. Park (1923) has described how a colony can store a limited amount of water for a day or so in the honey sacs of " reservoir " bees. In very hot weather drops of water are *deposited* in the hive, and by evaporation help to cool it (Parks, 1928 ; Fyg & Lotmar, 1947), but this is hardly water storage.

It is well established that the bees need these large quantities of water in spring because they are rearing brood, and that the greater the rate of brood rearing the greater the rate at which water is used. It is not necessarily true that all this water is used by the nurse bees for feeding the brood. In the first place, since the temperature differences within the hive produce currents of air, some of the water must be lost by evaporation—indeed it is this very loss, and the necessity for it in summer and winter, which we have already been discussing.

Approaching the problem from a different point of view, one can try to *calculate* the amount of honey, pollen and water required to rear, say, 1,000 bees to maturity in a normal colony. Such a calculation is beset with difficulties, because of both the incompleteness of the experimental data available and the many variations in conditions of even a normal colony in which brood is reared. But using such results as are available, calculations suggest that the water available from the honey and the pollen used by the colony in rearing 1,000 bees might provide a considerable fraction of that required, if all of it could be retained by the colony. If this were true it would mean that much of the water collection in spring is necessitated by water losses from the colony due to evaporation, etc. Even if it were only partly true, it raises the question: how much ought we to ventilate our hives in spring? During the rest of the year thorough ventilation is desirable, but it seems possible that during this one period, between the commencement of brood rearing on an appreciable scale and the first major nectar flow, such ventilation may be little more than quixotic, forcing the bees to collect extra water which will only be evaporated away again after they have brought it into the hive.

CONCLUSION

As I said at the beginning, I have avoided the subject of individual bees and the water they use, and do not use, in order to leave time to discuss the water balance of the colony as a whole. We have seen how in summer bees must remove large quantities of water from nectar in order to produce a concentration of sugars which will prevent fermentation, and also how, in very hot weather, they fetch water and hang it in drops in the hive where it will by evaporation reduce the temperature there. We have seen also how in winter the colony still has surplus water to dispose of, and how the beekeeper can arrange the hive so that it *is* disposed of. Lastly, we have seen how in spring the "water balance" of the colony is reversed, and how water, for the past nine months a waste product, becomes a useful commodity which must be fetched into the hive: water is very precious to the bees in spring.

It must be understood that in practice the divisions between the simplified "seasons" used in this lecture are flexible; the "spring" condition recurs in summer in periods when little or no nectar is available; the "summer" condition recurs during autumn feeding, and so on. I have only touched the fringe of a subject about which we still have far more to learn than we know already.

REFERENCES

Beutler, R. (1949) Ergiebigkeit der Trachtquellen. *Imkerfreund* **4**, 207.

Brown, E. C. (1950) Personal communication.

Dugat, M. (1950) Les micro-climats en apiculture. *Cahiers apic.* **1**, 41.

Fasold, J. (1911) *Münch. Bienenztg.* **33**, 29.

Fyg, W., & Lotmar, R. (1947) Unpublished results quoted in Steiner, A. (1947) Die Wärmehaushalt der einheimischen sozialen Hautflügler. *Beih. Schweiz. Bienenztg.* **2** (16), 139.

Gendot, G. (1907) Eau necessaire aux abeilles. *Apiculteur* **51**, 164.

Gooderham, C. B. (1938) Relation of strength of syrup fed to amount of food stored. *Canad. Dep. Agric. Progress Rep. Dominion Apiarist*, 1934-36, 13.

Hazelhoff, E. H. (1941) De luchtverversching van ein bijenkast gedurende den zomer. *Maand. Bijent.* **44.**

Park, O. W. (1923) Water stored by bees. *Amer. Bee J.* **63,** 348.

Park, O. W. (1946) The hive and the honeybee, ed. R. A. Grout, p. 165. *Hamilton : Dadant.*

Parks, H. B. (1928) Water storage by bees. *Iowa State Apiarist Rep. for* 1928, 53.

Pickel, G. (1911) *Münch. Bienenztg.* **33,** 205.

Vansell, G. H. (1942) Factors affecting the usefulness of honeybees in pollination. *Circ. U.S. Dep. Agric.* No. 650.