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CLIMATIC CONDITIONS AND BEE BEHAVIOUR

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Introduction. Demuth (1919) states that there are four factors which combine to make up the honey crop that a bee-keeper hopes to get, namely, (1) a surplus population of adult bees ready for field work, (2) a pronounced storing instinct and a minimum of swarming impulse, both of which depend upon the race of bees handled, (3) a good pasturage and (4) suitable weather conditions which would not impediment flight of bees on the one hand, and which would on the other hand stimulate secretion of nectar in plants. Root (1929) adds that "some advances have been made within recent years in a study of climatic factors on a few plants, but there still remains much to be done, and bee-keeping will not be a safe business until far more is known about these effects". Ramakrishna Ayyar and Ramachandran (1934) observe that the most important factors which contribute to the general health and prosperity of the bees are "(1) availability in the vicinity of sufficient pasturage for gathering honey and pollen, (2) the climatic conditions prevailing and (3) the absence of enemies like the wax moth". They point out also that "we have hardly any previous records on these points with regard to South Indian conditions".

The present investigation was undertaken to find out the relationship that exists between climatic conditions, chiefly temperature and relative humidity, and bee behaviour as indicated in the activity of the bees and the change of weight of a hive. Hambleton (1925) has studied in U. S. A. the effect of weather upon such changes in weight during the honey flow. The practical bee-keeper is concerned about the net gain per day per colony which to him represents a surplus of honey available for extraction during the honey flow season. The importance of determining the various climatic conditions which influence his honey crop cannot, therefore, be over estimated.

Pasturage conditions. That the availability of adequate pasturage is the chief determining factor for a good honey crop can be easily admitted. But with the present information, it is hard to state whether given the same pasturage conditions, bee-keeping will be successful in all localities. The question is closely related to the relationship that exists between temperature and relative humidity to nectar secretion in flowers. Again different plants may possibly react differently to identical climatic conditions. It is, therefore, necessary to indicate at the outset the plants that formed the chief source of nectar in the locality which was studied in the present investigation.

The apiary is situated about three miles from Coimbatore town, and the study was undertaken in April—May 1937. Tamarind (*Tamarindus indica*) flowers were available in very great profusion close at hand and this was the chief source of nectar. To a smaller extent the second crop of flowers in cotton formed pasturage of minor importance, but they were available only about 500 yards away from the location of the apiary. Of lesser importance were flowers of guava (*Psidium Guajava*), the cactus (*Pachycereus marginatus*), coconut (*Cocos nucifera*) and *Antigonon leptopus*. These plants were useful either for pollen or nectar or for both. Particular mention should be made of the cactus which blossomed before 5-30 a. m. and numerous bees were seen inside the flowers which formed the chief source of pollen between 6 and 7-30 a. m. Till about 8-30 a. m. incoming bees were seen to bring full loads of pollen. But during midday and the afternoon incoming bees were seen to be least possessed of pollen and it was, therefore, concluded that they came chiefly with nectar, for bees rarely make flights when either nectar or pollen is not available. It has also been observed by experience that the period during which the present study was conducted falls almost in the middle of the main honey flow season in that locality.

Materials and Methods. Two bee colonies of *Apis indica* (hereafter referred to as hive *A* and hive *B*) of average strength with full set combs in one super were mounted on a Salter's family weighing scale and hourly reading of weight from 5 a. m. to 7 p. m. were taken. The hours from 5 a. m. to 7 p. m. were, by observation, found to be the period during which bees were seen at outdoor work. Readings were taken correct to half an ounce (1 oz. = 28·35 gms.). Simultaneously temperature in shade was noted by means of a wet and dry bulb thermometer and the relative humidity was then read off from the appropriate tables. Pearson's co-efficient of correlation was worked out wherever possible.

Discussion.

Changes of weight. (I) *General.* The variation in the weight of a hive is due to the following causes:—

(1) Loss of weight on account of evaporation of moisture from the contents of the combs.

(2) Loss of weight on account of metabolism in the body of the bees.

(3) Gain in weight on account of the loads of pollen and nectar gathered by the bees.

(4) Changes in weight due to the weights of incoming and outgoing bees during the day time.

(5) Changes in the numbers of bees in the hive by reproduction, destruction etc.

Of these five factors that contribute to the change of weight items (1), (2) and (5) happen throughout the day and night. The rate of loss on account of evaporation depends chiefly on the temperature and relative humidity, while loss due to metabolism is considerably increased if bees do more work. The gain in weight of a colony is due to incoming loads of pollen and nectar brought by bees. Since it is found that the outdoor activity of the bees, during the course of the present study, has been confined to the "diurnal hours" from 5 a. m. to 7 p. m. and since almost all the population of the colony is within the hive at 5 a. m. and 7 p. m., the differences in weight-readings taken at these hours are not likely to be caused by the weights of bees remaining outside the hive. Increase or decrease in the population of the hive, variation in weight on account of death of bees, if any, or loss of population due to other causes has been taken as negligible and therefore disregarded. Over a small period of time, changes of weight due to these causes will be relatively very small. The hive is made of wood which will absorb varying amounts of atmospheric moisture depending upon the climatic conditions, but these changes have been ignored since they would be slight in view of the fact that hives have been in use for over five years.

Since Root (1929) has pointed out that unless the storage of honey in the supers found in the honey flow season (which is spread over a long period) is removed, bees get lazy and tend to crowd in the hive itself, honey from the super was removed, after recording the weights, for six days continuously, to make them work sufficiently fast. An interval of three days was allowed for the above mentioned operations and readings were again taken for another period of six days continuously. This procedure was followed throughout the study. Both hives *A* and *B* were also under observation for a period of four days continuously. Hourly readings of weight were recorded in all cases.

(ii) *Net gain of weight.* In table I the frequency distribution of hourly changes of weight for hive *A* alone for 21 days is given. The difference of weights between the readings taken at 5 a. m. and 7 p. m. which represents the net gain or loss for the day, shows that out of the 21 readings available, on two days there have been net losses of weight of 2 oz. and 0 5 oz. respectively, on three days there was no change of weight, and in all other cases a gain of weight has been recorded. The average gain in weight for the 21 days amounts to 1·8 oz. per day and there is a net gain of even 4 oz. per day.

It is not possible to easily obviate the loss due to evaporation and metabolism. Losses due to evaporation should be considerable, and but for this, there should be a much larger gain in weight.

(iii) *Midday increase.* While a comparison of the readings taken at 5 a. m. and 7 p. m. would obviate the error due to the loss of weight on account of the bees being engaged in field work, the hourly readings taken between these hours introduce this error also. If we imagine for a moment that there is no evaporation and that between 5 a. m. and 7 p. m. the bees are engaged in outdoor work, then the weight recorded at any time between these hours should be less than the reading taken at 7 p. m., for the reason that a smaller or larger number of bees are outside the hive. But there have been very few cases when the readings taken earlier than 7 p. m. and later than 11 a. m. were less than the weight recorded at 7 p. m. This increase is due to the honey and pollen collected during the day by the bees.

Table I.

Frequency distribution of changes of weight of hive A with 5 A. M. weight as the base (Observations on 21 days.)

Changes of weight in oz.	Time in hours from midnight.													
	6	7	8	9	10	11	12	13	14	15	16	17	18	19
-2·9			1		1	1	1							1
-1·5	1		1	2	1									
-1·0	1	1	1	1	1			1	1				1	
-0·5	4	2	1	1	1	1							1	1
0	15	12	10	3	2	2	2					2	1	3
0·5		4	1	7	4	2				1	1		1	1
1·0			1		3	4	3	4	3	3	1	3	2	1
1·5		1	2	3	2	4	2	1	2	2	2	2	2	3
2·0		1	3	2		1	2	2	3	1	5	2	2	2
2·5				1	2	2	2	1					1	1
3·0				1	2		1	1	1	2			5	4
3·5							2	2	1	1	2	6		1
4·0						1	1	1	1	2	1	2	4	3
4·5					2			2	1	1	3	2	1	
5·0						2	1	2	2	2	4			
5·5							2	1		1				
6·0							1	1	3					
6·5							1	2	2	3	23	2		
7·0						1				2				
Mean oz.	-0·2	0·2	0·3	0·6	1·1	1·7	2·6	3·3	3·5	3·1	3·4	2·9	2·2	1·8

The maximum weight was recorded between 1 p. m. and 4 p. m.; and during these hours the average gain in weight was between 3 oz. and 3·5 oz. As much as 6·5 oz. or 7 oz. have been added to the weight of the hive before these hours.

(iv) *General trends.* Hambleton (1925) has observed in U. S. A. that the "diurnal hours" from 6 a. m. to 7 p. m. is divided into four stages during the spring honey flow. The one from about 6 a. m. to about 10 a. m. is the period when the hive loses weight. He has explained this morning loss as due to the bees leaving in flight. During the second stage which immediately follows upto about midday, the hive steadily gains in weight after which (the third stage) for about an hour between 1 p. m. and 2 p. m. the rate of gain slackens. Hambleton explains this by stating that "until further investigations are made Bonnier's observations of decreased nectar secretion and the resulting effect on bee behaviour must be accepted as the most logical explanation of this phenomenon, although the reasons which he gives for these changes on the part of the plants and the bees do not seem entirely satisfactory". After about 2 p. m. which is the fourth stage, the hive gains in weight till about 7 p. m.

In the present study, ordinarily the hive was found to undergo no change of weight between 5 a. m. and 6 a. m. Out of the 21 readings available for hive A, 15 readings show that there has been no change of weight and 6 readings show a loss (Table I). After 6 a. m. the hive began to gain weight and this increase continued till about 2 p. m. after which hour the weight began falling. On some days as on May 9, 1937, there was a depression between 11 a. m. and 1 p. m. and on other days this fall was totally absent. On April 11, 1937 it was found that losses of weight were recorded between 8 a. m. and 2 p. m., and on April 12, 29 and 30 between 8 a. m. and 11 a. m.

The large fall of weight occurring between 2 p. m. and 7 p. m. may be due to two causes working simultaneously. While on the one hand, as Hambleton has stated, there may be a decreased nectar secretion, and so less honey gathering by bees, the rate of evaporation on the other hand should also be greater since the temperature is very high and relative humidity low at about 2 p. m. As much as 3 oz. have been lost on some days during the afternoon for a net weight of about 9 lb. (very approximate and only estimated) of the combs (exclusive of the weight of the wooden frames and hive). There was an average loss of about 1·7 oz. during the afternoons for the readings taken on 21 days.

In graph I the changes of weight of colonies *A* and *B* as on May 9, 1937 are shown, and in graph II the tendencies in change of weight for hive *A* alone, for each of the three periods of six days and for a period of three days during which the hive was continuously on scale is indicated.

(v) *Two hives compared for change of weight.* It will be evident from graph I that hives *A* and *B* show similar tendencies for change of weight. In fact this has been the case on all the four days during which both the hives were compared. Table II furnishes the changes of weight of each of the hives at various hours.

Table II.

Trend of changes of weight of two hives A *and* B *with 5 a. m. weight as the base (in oz)*

Date of observation.		7 a.m.	9 a.m.	11 a.m.	1 p.m.	3 p.m.	5 p.m.	7 p.m.
May 9, 1937	A	0·5	3·0	7·0	6·5	7·0	3·5	3·0
	B	−1·0	0·5	3·0	2·0	4·0	0·5	−0·5
May 10, 1937	A	2·0	2·5	5·0	4·5	5·5	3·5	2·0
	B	1·0	4·5	5·5	5·0	4·5	2·5	0·5
May 11, 1937	A	−2·0	1·0	3·0	4·5	3·0	Not available for hours from 5 p. m. to 7 p. m.	
	B	1·0	3·0	3·5	5·5	2·5		
May 12, 1937	A	0	2·5	4·5	5·0	3·5	−0·5	−0·5
	B	0	2·0	5·0	4·0	3·5	−2·0	−2·0

The similarity probably indicates that given identical environmental conditions bees work to their maximum. Else the trends of change of weight would not have been so alike. Of course, the amount of gain in weight should always depend on the force of field workers available for collecting pollen and nectar. Favourable environmental conditions for collecting nectar help the working of bees in different colonies in the same manner. The two colonies were caught at two different places in different years and they have shown similar responses to environmental conditions. How sharply bees of each colony respond to environmental conditions is a different question and that will be dealt with later in this contribution.

The results now obtained are in general agreement with Hambleton's views.

(vi) *Nocturnal loss.* There is also loss of weight during nights which may be due to evaporation from the honey and metabolism in bees. In Table III the frequency distribution of loss by night is indicated.

Table III.

Frequency distribution of Nocturnal loss of weight.

	Loss of weight in oz.					Total
	0	0·5	1·0	1·5	2·0	
No. of days	6	5	3	...	2	16

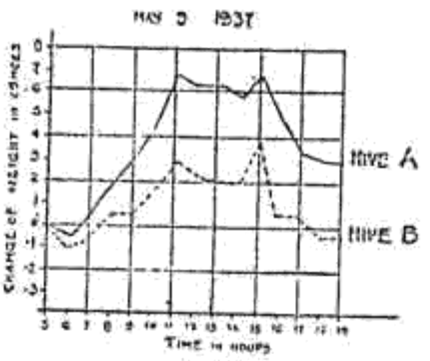
Only 16 readings are available and the mean loss for these readings is about 0·6 oz. per night. This is very small when compared with the loss due to evaporatton in the afternoons. It is, therefore, likely that the loss during the night is largely due to metabolism, and evaporation may be insignificant as the relative humidity is higher and temperature lower during the nights. The six zero readings indicate that losses due to metabolism are balanced by absorption of moisture during the nights when the humidity is high and temperature is low.

Flight of Bees. Three factors usually operate on the number of bees entering a hive in a given interval of time. Firstly if pasturage is available close at hand, each bee can perform a greater number of trips in a given interval of time. Secondly even if pasturage is available nearby, unless nectar secretion is profuse or pollen is available in abundance, bees would not be in a position to collect the optimum load quickly, that is, they will have to visit a larger number of flowers before they "think" of returning to the hive. This would naturally take a longer time and so the number of bees entering a hive in a definite period will be less. Thirdly the environmental conditions obtaining outside by way of temperature, velocity of wind, rain etc., should be such as would not impediment flight of bees.

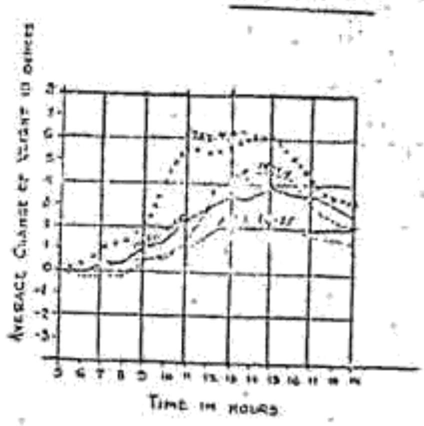
In a particular locality the number of bees that enter a hive in a given interval of time should account for the increase in weight and unless the incoming bees bring sufficient loads, the hive should record a fall of weight due to loss on account of evaporation.

Rough counts of the number of bees in hives *A* and *B* entering in one minute were made from 5 a. m. to 7 p. m. at intervals of 15 minutes. It was not possible to record the number of bees, if any, entering between 5 a. m. and 5-45 a. m. as there was not sufficient light available. It was easier to record the number of bees alighting at the entrance to the hive,

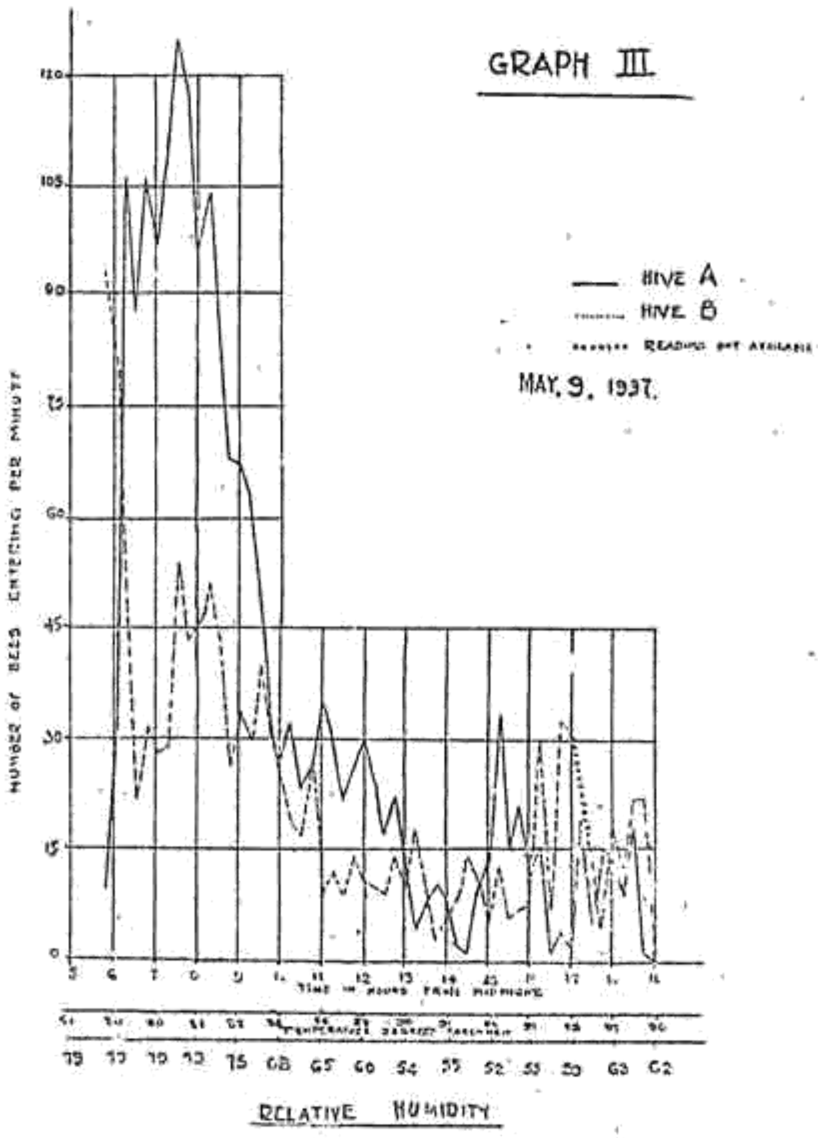
GRAPH. 1



GRAPH II



GRAPH III



rather than the bees that were leaving the hive. Moreover, it is only the number of bees that return to the hive that matters for the increase in the weight of the hive due to the incoming loads of pollen and nectar. The need for an automatic device for counting was not very keenly felt, since it was found very easy with some experience to count over 50 incoming bees per minute. The occasions when larger number of bees was to be counted were very few and even here much difficulty was not experienced.

Of the observations for four days recorded, those of 9th May are represented in graph III, the records for the other days being similar. It will indicate that bees are busy in the early hours of the morning rather than at midday or in the afternoon. It will also be seen that hive *B* has started work earlier than 5-45 a. m. and that is the reason why as many as 94 bees were seen to enter the hive in one minute at this hour. Hive *A*, however is seen to increase in activity as time advances and at 6-15 a. m. the count has increased to 106, while the graph for the hive *B* is already falling.

The trends of graphs I and III may now be examined. It will reveal that till about 9 a. m. the rate of increase of weight of the hives is very small although the number of incoming bees is very large. This is due to the fact that the loss of weight of the hive on account of bees leaving in flight has first to be compensated and this naturally takes a longer time.

The trends of both graphs I and III are alike after 11 a. m. The depression between 11 a. m. and 3 p. m. is repeated in graph III and the peaks at 3 p. m. followed by a fall occur in both the graphs. After 11 a. m. when the temperature rises bees do not go out for field work as is reflected in graph III. This fall in the activity of bees may be due to decreased nectar secretion in flowers. After 3 p. m., however, the activity is seen to have increased but the loads brought in by the field force is not sufficient to compensate the loss of weight of the hive on account of evaporation. During the afternoons as much as 3 oz. has been lost in the weight of the hive on some days, while the average is about 1·5 oz.

Ghosh (1936) has stated that " more nectar is secreted in the morning and evening than in the middle of the day " and the above observations of the number of bees entering the hive at specific intervals of the day appears to confirm this statement.

If it is assumed that the number of bees entering in one minute recorded at fifteen-minute intervals is fairly representative of the activity of the hive, then the total number of bees entering per minute say at 8 a. m., 8-15 a. m., 8-30 a. m., 8-45 a. m., added together furnishes an index of the aggregate activity of the hive between the hours 8 a. m. and 9 a. m., and the difference in weight of the colony recorded at these hours should bear some relationship to the above index. Of course, loss due to evaporation is always happening. The correlation between the number of bees entering in one minute recorded at intervals of fifteen minutes and the difference in weight of the hive recorded during two consecutive hours, shows a significant correlation of $+0.5409 \pm 0.048$ for hive *A* and 0.5715 ± 0.0649 for hive *B*. But for the error introduced by varying rates of evaporation, this correlation should be much higher. The conclusion that more frequent flight of bees should account for a larger increase in weight should, therefore, be correct.

Nectar Secretion, Climatic Conditions, and Flight. It has been shown that flight, i. e., the number of incoming bees, is an index of the changes in weight of the hive. It ts, therefore, possible to utilise flight records in analysing the effect of climatic conditions on the colony. Relative humidity and temperature are the two factors that could be measured conveniently.

It is well known that it is possible to make the bees active even during dark hours by directing a beam of light from a torch to the entrance of the hive. Were the light to be switched off the bees would be lost, as they are unable to perceive during darkness. Sunlight is, therefore, necessary for visual perception. Strong wind and rain act as impediments and prevent flights. Within the normal limits of temperature and humidity which prevail at Coimbatore, the availability of pollen and nectar seems to be the only limiting factor for the activity of bees. That relatively high temperatures which prevail between 1 p. m. and 3 p. m. do not appear to affect the flights is very easily seen from the fact that if a cotton wool soaked in honey is placed at about 100 yards or more from the hive, the bees, in spite of the hot hours, gather around the soaked cotton wool. This is a very common observation at any part of the day when extraction of honey is going on. It is, therefore, clear that provided extremes of temperature and humidity are not met with, temperature and humidity affect the bees indirectly by either causing scarcity or profusion of nectar and pollen and by influencing blossoming. A study of the relationship between the flight of bees and these two climatic factors really, therefore, amounts to a study of nectar secretion in plants.

Temperature. Phillips (1926) observes that " any species of nectar-secreting plant is often rendered non-productive by unfavourable weather conditions. The smaller plants usually cease nectar secretion at once in dry weather, while the tree sources are less quickly affected". Root (1929) states that " for the majority of the plants there is a decrease in the amount of nectar until about the middle of the afternoon, when the amount is least, followed by some increase toward the close of the day. This change may be due to higher temperatures at midday, or may be due to lowered relative humidity when the temperatures are highest".

Hambleton (1925) has arrived at a correlation of $+0.7529 \pm 0.0473$ between net gain in weight of a hive and the average day temperature; it must be remembered that in U. S. A. temperatures are generally low, and, therefore, high temperatures in U. S. A., which would be comparable to our low temperatures, are beneficial. Since losses due to evaporation reduce the increase in weight of the hive, the flight activity of bees may be taken as a better index for ascertaining the effect of temperature on nectar secretion than the change of weight. In the present study a significant correlation of -0.6084 ± 0.0658 was obtained between flight of bees and day temperature. This negative correlation indicates that as temperature increases the flight activity of the bees decreases indicating retarded nectar secretion. Since there is a positive correlation between flight of bees and change of weight, lower temperatures should account for a larger honey crop.

It may be concluded that given the same pasturage conditions, a larger honey crop can be obtained at lower temperatures. In the present study the temperature ranged from 77°F to 92°F between 5 a. m. and 7 p. m. with the average ranging from 82°F to 87°F. Oertel (1937) has studied in U. S. A. the data in respect of the honey crop obtained over twelve years in relation to the average temperature in each year, and concludes that larger honey crops are associated with temperature deviations below normal. This conclusion is also in conformity with the inference stated above.

Humidity. Relative humidity accounts for the large evaporation in hives. Effects of humidity are always co-existent with the effects of temperature while both temperature and humidity are related. It is, therefore, very difficult to assess the effects of humidity on bee behaviour exclusively. There is a very high negative correlation of -0.8802 ± 0.006 between temperature and humidity which indicates that as temperature rises humidity falls. Between flight and humidity a positive correlation of $+0.8484 \pm 0.027$ has been obtained and this shows that higher humidities are conducive to an increased flight activity of the bees which is an index of more profuse nectar secretion. Phillips's (1926) observations that lower relative humdities retard nectar secretion is confirmed.

In the forenoon, temperature is low and humidity is high and the nectar secretion is, therefore, greater in the early part of the day.

Summary and Conclusions. A study in the hourly change of weight of a bee hive is made, which shows that the hive gains till about 3 p. m. and then loses weight due to evaporation. An average net gain in weight per day of about 1·8 oz. is recorded, the afternoon loss alone being about the same, so that, but for the heavy loss of weight in the afternoons, a larger increase of weight should be recorded. There is relatively little loss of weight by nights, it being only about 0·6 oz. on an average. Two hives are also compared for change of weight and they are found to behave almost alike. When one gains in weight the other also gains in weight and so also when one loses weight.

The exact amount of gain in weight depends upon the field force. Observations of the number of bees entering the hive per minute on four days at fifteen minutes intervals have been made and a correlation of $+0.5409 \pm 0.048$ has been obtained between flight of bees and change of weight for hive A. A similar correlation of 0.5715 ± 0.0649 was obtained for hive B. It is also seen that bees are busier in the mornings than at midday or in the afternoons. In the matter of behaviour of the population in each hive, it is observed that one colony starts work earlier than the other.

Provided that extremes of temperature and impediments like darkness, high wind and rainfall are not met with, the activity of the bees is found to entirely depend upon the blossoming of flowers and availability of pollen and nectar. The necessity for studying the effect of temperature and humidity on nectar secretion and anthesis is, therefore, keenly felt. It has been shown that the flights indicate this floral activity, and utilizing flights as an index of the condition of the pasturage, it has been proved that nectar secretion is larger in the mornings than at midday or in the evenings, and that lower temperatures cause larger nectar secretion. It is therefore concluded that when the pasturage is identical a larger honey crop can be expected from the locality having lower temperature.

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