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THE EFFECT OF SPRING FEEDING ON THE DEVELOPMENT OF HONEYBEE COLONIES

B.B.K.A. RESEARCH COMMITTEE REPORT BY E. E. CRANE

INTRODUCTION

The provision of sugar syrup in spring is one of the many beekeeping operations about which great, and often spirited, difference of opinion is displayed. This paper describes the first of several investigations undertaken by the Research Committee of the British Bee-Keepers' Association to obtain quantitative information as to the benefit, if any, of spring-feeding colonies kept under normal beekeeping conditions in various parts of England. It was also hoped—and this hope has to some extent been realized—that the results would throw some light on the *reason* for the main differences of opinion on the subject.

The two schools of thought with regard to the spring feeding of colonies which have adequate stores are reflected in textbooks of beekeeping. Digges (1936) states 'Bees are fed in spring . . . . . . to "stimulate" them . . . . . . *i.e.* to produce more rapid brood-rearing'. Wedmore (1945) suggests that 'stimulation in spring has the advantage that old and perhaps diseased bees are disposed of by being worked to a full stop'. Other writers come out boldly against spring stimulation. Root (1940) says that while spring feeding used to be the custom, experience shows that it 'very often does more harm than good', and Hamilton (1945) gives it as his opinion that 'a good colony needs no stimulation in spring, and a poor one is often better without it, unless the weather is good'.

While the authors quoted represent widely diverging views as to the value or harm of providing syrup in spring to colonies not short of stores, all tacitly agree that, even if it does harm in other ways, it *does* increase the rate of brood rearing. However, Butler (1946) carried out carefully controlled experiments with 28 matched colonies given ample winter stores, and he deduced 'that spring feeding leads neither to stimulation of the colonies nor to an increased rate of colony development'.

Meanwhile the Ministry of Agriculture still compromises by issuing permits for sugar for spring feeding but giving the beekeeper the option of buying this sugar in the preceding autumn.

Here we have a characteristic problem in beekeeping method : beekeepers with a lifetime of experience differ as to whether the net effect of spring feeding is good or bad, and a controlled experiment seemed to show that it has no appreciable effect either way. Are the results of long experience invalid, and if so, which ? Is it safe to apply the results obtained in one experimental station to beekeeping conditions elsewhere ? These are some of the questions which led the Research Committee of the British Bee-Keepers' Association to undertake the present investigation.

MATERIAL

One hundred and thirty-one pairs of matched colonies were used for the experiment. The colonies, owned by a total of 86 beekeepers, were located in 33 English counties, the south being more strongly represented than the north. The beekeepers themselves were mostly selected amateurs, whose services were recruited by the B.B.K.A. Research Committee through Research Officers in each county.

The use of matched colonies was suggested by Dr. A. L. Gregg and Mr. E. B. Wedmore. The two colonies of each pair were selected in February 1948 from *three* colonies with adequate stores, matched by their owner in the autumn of 1947 with regard to age and merit of queen, strain or kind of bee, strength in bees and brood, winter stores, type of hive and ventilation arrangements. Table 1 gives details of the pairs of colonies used, together with similar details for Butler's experiment (Butler, 1946).

TABLE 1

Details of colonies used for spring-feeding experiments

		CRANE 1947-48	BUTLER (1946) 1944-45
No. fed colonies		131	9
No. unfed control colonies		131	10
Deliberate through ventilation		47 pairs yes 84 ,, no	19 yes
Age of queens		74 pairs young (1947) 51 ,, older 6 ,, unknown	19 young (1944)
Strain of bee		14 pairs "black" 73 ,, "yellow" 41 ,, "hybrid" 3 ,, no statement	19 Italian
AUTUMN STORES	Carbohydrate (as lb. honey)	7 pairs 25-29 lb. 58 ,, 30-39 lb. 48 ,, 40-49 lb. 18 ,, over 50 lb.	19 35 lb.
	Pollen	6 pairs poor 33 ,, medium 92 ,, good	19 abundant
SPRING FEEDING	Period	March & April 1948	March & April 1945
	Total wt. fed (as lb. honey)	Average 9·2 lb.	12·5 lb.
	Wt. fed per week (as lb. honey)	1·25 lb.	3·7 lb.
FINAL EXAMINATION	Carbohydrate stores (as lb. honey)	Averages 16·2 lb. control (131) 20·6 lb. fed (131)	Averages 15·0 lb. control (10) 15·4 lb. fed (9)
	No. frames covered by bees	Averages 12·6 control (131) 13·6 fed (131)	Averages 12·1 control (10) 11·1 fed (9)
	Date	End April-early May	End April

1 kg. = 2·2 lb.

METHODS

a Experimental methods

The conditions of each group of three colonies were recorded on a standard form at the time of the autumn examination 1947. In early February 1948 the behaviour of each colony was observed during a cleansing flight, and a record made of the proportion of bees flying, whether pollen was being collected, signs of disease or starvation, and finally the estimated strength of the colony (as strong, medium, weak, dead). Details were also recorded of the distance and nature of the water supply used by the bees.

The information sent in for each group of three colonies was scrutinized, and the pair which seemed most similar was chosen for the experiment. Of this pair, one was allotted for feeding by a table of random numbers. The beekeeper was instructed to feed this colony with 1 lb. sugar dissolved in 1 pt. water (440g./l. solution), from the first half of March until the white horse chestnut (*Aesculus hippocastanum)* was in bloom (see Table 1). Feeding was carried out once or if preferred twice a week, with a rapid or slow feeder. By request some colonies (9) were fed with a honey solution of the same sugar concentration ($1\frac{1}{4}$ lb. honey dissolved in $\frac{3}{4}$ pt. water, *i. e.* 570 g./l. solution). The other colony of the pair was left unfed. Instructions were given that similar ventilation should be maintained in the two colonies during feeding.

The final examination of the colonies was made when the white horse chestnut was in bloom; the reasons for this choice are as follows. It was desirable that this final examination should be carried out as late as possible, but before the first major nectar flow which might mask any effect of spring-feeding syrup—about May 1st in the south of England. The Phenological Reports of the Royal Meteorological Society show that the development of spring is better represented by the dates of flowering of certain plants than by any system based on the calendar and geographical divisions. Now the average initial date of flowering of the white horse chestnut over 35 years was May 1st in the south-west of England, May 19th in the north-west and intermediate dates for the rest of England (Clark, Margery and Cave, 1934). Moreover the white horse chestnut is widely distributed throughout Britain, and was available to all those taking part in the experiment. As a result of the advanced spring of 1948 the white horse chestnut bloomed early, and most final examinations were carried out in the last week of April or the first week in May.

At this examination the hives were opened up and the following details recorded for each colony:

1. Size of frames
2. Number of brood frames covered by bees
   Number of shallow frames covered by bees
3. Number of brood frames containing brood
   Number of shallow frames containing brood
4. Amount of honey present (in lb.)
5. Food supplied (in lb. honey or sugar)
6. Method of feeding used.

The instructions given were:

1. Compare the number of frames covered on both sides with bees, the observation being made of both hives at the same time in the same way, a quick estimate being made with a minimum of disturbance.
2. Brood and eggs should be counted together. The number of frames containing any brood or eggs should be recorded, but if only one side has eggs or brood this should be counted as a half.
3. It is important that the estimate of the amount of stores in each hive in a pair should be made by the same person. Unsealed stores should be included.

b Treatment of experimental results

Any apparent discrepancies or queries were referred back to the observer immediately. Results from any pair of colonies were rejected if one or both of the colonies was found to be dead or queenless or was known to be robbed, if it was found or suspected to be diseased or poisoned, or if it swarmed before the final spring examination.

Any results for frames other than the $14 \times 8\frac{1}{2}$ in. British Standard Brood Frame (B.S.B.F.) were converted by multiplying by a factor comb area of frame / comb area of B.S.B.F. In this paper 'frame' refers to the B.S.B.F. unless otherwise specified.

Satisfactorily completed results for each pair of colonies were entered on a 5 × 3 in. Paramount sorting card. This information was transferred to holes punched along the edges of the card, each hole representing some condition, or value of a variable. For example, hole number 3 represented the age of the queens heading the pair of colonies. If they were young (1947) queens, the hole was slotted out by a pair of ticket nippers; if they were older, the hole was left unslotted. In order to separate cards representing pairs of colonies headed by old and young queens, the 131 cards were stacked, a sorting needle passed through hole number 3 and lifted. The cards in which the hole had been slotted (1947 queens) fell out and were thus separated from the rest. The two piles of cards could then be sorted further (*e.g.* for differences between fed and control colonies) by the use of other holes which represented the requisite data.

RESULTS

a Colonies withdrawn from the experiment

Figures relating to casualties among bee colonies in winter and spring are so hard to come by that details are given here of the colonies which seceded from the present investigation, which was carried out during a comparatively 'open' winter and spring. In autumn 1947 details of 531 colonies were recorded, owned by selected amateur beekeepers. By February 1948, 27 colonies had been withdrawn owing to their owners' illness, etc. Information for the remaining 504 colonies was returned in February 1948, 496 apparently healthy, six suspected of disease (unspecified) and two dead. The number of colonies rejected according to the design of the experiment was 135, and instructions were given for 354 (177 pairs) to continue.

At the final return after the spring examination, 27 pairs of colonies were withdrawn from the experiment owing to illness or defection on the part of the beekeepers, and 19 pairs were withdrawn on account of the condition of one colony (or both) of each pair. Details of these 'casualties' (21 colonies out of 310 reported on) are as follows:

Dead	3
Poisoned	4
Diseased	2
Robbed	1
Queenless	4
Swarmed	1
Fed to prevent starvation	6
	21

There were left 262 colonies (131 pairs) which constituted the final material for the experiment.

TABLE 2

Combined results of the development (to the time of the spring examination) of 131 pairs of matched colonies, one colony fed syrup in spring and the other (control) colony not fed

	No. frames covered by bees			No. frames containing brood			'Net stores consumed' (as lb. honey)		
	Mean	*s.e.*	*v*	Mean	*s.e.*	*v*	Mean	*s.e.*	*v*
Fed colony (F)	13·6	±0·44	0·37	9·1	±0·28	0·35	30·2	±1·04	0·40
Unfed colony (C)	12·6	±0·39	0·36	8·2	±0·23	0·32	24·8	±0·91	0·42
F-C (average of differences)	1·03	±0·30	3·3	0·89	±0·27	3·5	5·37	±0·76	1·6
F-C (difference of averages)	1·03	±0·59	6·6	0·89	±0·36	4·7	5·37	±1·38	3·0

s.e. = standard error of mean

$$v = \text{coefficient of variation} = \frac{\text{standard deviation of distribution}}{\text{mean value}}$$

Deaths reported before February were 2 per 1,000 and between February and May 10 per 1,000; queens lost, 13 per 1,000. Colonies were not specifically examined for disease, and it is likely that many slight attacks were not recorded. It is also possible that losses were proportionately higher among colonies for which returns were not sent in, and among the 135 rejected colonies. The total loss of material due to the conditions of the colonies was 11%; due to unavoidable withdrawals from the experiment 8%; and due to defection on the part of the bee-keepers 11%.

b General results of spring feeding

The spring development of the fed and control colonies in the 131 pairs was compared in three ways:

a number of frames of bees
b number of frames containing brood
c net stores consumed between the autumn and spring examinations.

It should be borne in mind that *a* was unaffected by eggs laid later than say the first week in April—it represents the early spring development of the colony. On the other hand *b* represents more the late spring development (during the three weeks prior to the examination); it was of course influenced by *a*.

Only carbohydrate stores were included in *c*; they were measured throughout in 'lb. honey'. Honey was assumed to contain 80% sugar, and weights of sugar were converted into weights of honey by multiplying by 1.25. The percentage of sugar, fed in autumn syrup, which is stored by the bees varies with the concentration of the syrup (Gooderham, 1938; see also Ribbands, 1950). With syrup made of 2-2½ parts sugar to 1 part water, Gooderham found that the food stored was about 92% of the sugar fed; on this basis the assumption used here that all the sugar was stored would introduce a 6% error in calculating the autumn stores of a colony with 30 lb. honey and 10 lb. sugar fed as syrup. On the other hand the whole of the sugar was taken by the bees, and used at some period, so that the effective error may well be less than this. No results are known for the useful percentage of sugar fed in syrup in spring.

The value of *c* 'net stores consumed' was taken to be (autumn stores − spring stores + weight fed (if any), as 'lb. honey'). Figures for these three items are given in Table 1. No attempt was made to estimate the weight of honey obtained from nectar gathered in 1948 before the spring examination: the same sources were available to both colonies of a pair. The total stores consumed would be 'net stores consumed' plus honey from nectar collected in 1948 before the spring examination.

Table 2 gives the combined results for the three quantities listed above. The fed colonies were significantly *ahead* of their unfed control colonies, by an average of 1·03 frames of bees plus 0·89 frames of brood. Both these mean differences are more than three times their standard errors given in line 4 (0·30 and 0·27 respectively), and the probability that they were due to chance is about 1 in 1,000.

This increase in brood and bees was attained at the expense of 5·37 lb. of honey, rather more than one brood frame full. In this combined result, the average extra consumption was not much more than half the average weight fed (9·2 lb. honey).

The coefficient of variation *v* (see foot of Table 2) gives a useful measure of the spread of the observations, independent of the units in which they are expressed and of the number of observations in the sample. Table 2 shows that *v* is between 0·32 and 0·42 for bees, brood and net stores consumed, for both fed and unfed groups of colonies. It is very much greater for the differences F - C.

Whereas the third line of Table 2 gives the standard error (*s.e.*) of the mean of the difference F - C for each pair, the fourth line gives *s.e.* of the difference between the averages for the fed group and the control group which are given in lines 1 - 2. The fact that these latter standard errors are nearly twice the former indicates the advantage, indeed the necessity, of using matched pairs of colonies for the experiment; they represent the standard errors if *any* 131 colonies had been fed and *any* 131 unfed, instead of matching in pairs and feeding one of each pair.

c Factors which affected, or did not affect, the benefit of spring feeding

Size of colony. In spring, as at other seasons, the size of a colony is one of the factors which determine its efficiency as a working unit. The present results were therefore analysed with respect to the size of the colonies. It must be pointed out that this analysis does not refer to matched *groups* of colonies; the only matching was between the two colonies of each pair. It is possible, therefore, that the effects shown in Figs. 1 and 2 were due not to the differences in colony strength but to some other factor or factors; the smaller colonies may have differed from the larger in some way other than size, and this difference may have been wholly or partly responsible for the results. However, since the possibility of carrying out experiments with large enough groups of differently sized colonies to settle this point is unlikely in the near future, the present results are published here.

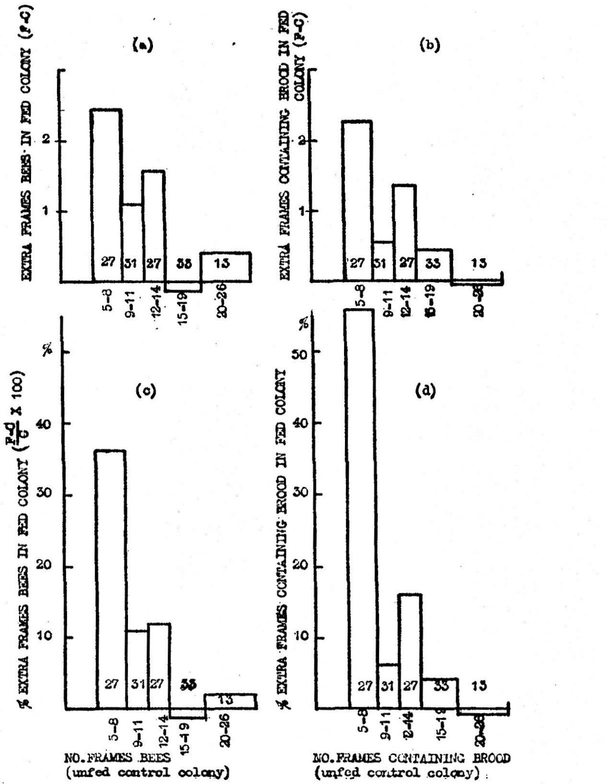

Fig. 1. Differences between fed and control colonies for colonies of different spring strengths.

a Extra frames of bees in fed colony
b Extra frames containing brood in fed colony
c Extra *percentage* frames of bees in fed colony
d Extra *percentage* frames containing brood in fed colony

Fig. 1*a* shows the average excess number of frames of bees in the fed colony, for colonies of different spring strengths, measured by the number of frames of bees in the unfed control colony. The divisions were chosen to give approximately the same number of colonies in each group. Fig. 1*b* gives similar information for brood. It is apparent from Fig. 1 that the benefit of spring feeding was much greater for small than for large colonies; instead of the gain in bees or brood being proportional to the size of the colony, it was more nearly inversely proportional. In Figs. 1*c* and 1*d* the gains are shown as percentages of the strengths of the control colonies. Small colonies had nearly 40% more bees and over 50% more brood than their unfed control colonies.

The gains in both bees and brood for the 5 - 8 frame colonies (27) and for the 9 - 11 and 12 - 14 frame colonies together (58) are significant, the probability that the gain in brood or bees of either group is due to chance being not more than about 1 in 1000. On the other hand the gains and losses shown in Fig. 1 for the 46 colonies covering more than 14 frames are not significant.

Fig. 2 shows the relationships between the average autumn stores, spring stores and 'net stores consumed' between autumn and spring, for colonies of different spring strengths. In Fig. 2*a* they are grouped as in Fig. 1, in Fig. 2*b* they are grouped according to spring brood-strength, the divisions again being chosen to give approximately the same number of colonies in each group.

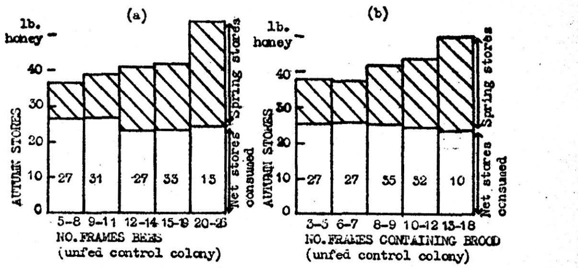

Fig. 2. Autumn stores, spring stores and 'net stores consumed' for control colonies of different spring strengths, *a* in frames of bees, and *b* in frames containing brood.

The average 'net stores consumed' was about 25 lb. per colony, and was almost independent of the the spring strength of the colony in bees or brood. The stores left in the hive in autumn were larger for large (spring) colonies than for small ones, probably because beekeepers tended to leave larger stores for colonies strong in the autumn than for those which were then small. The stores remaining at the spring examination, represented by shaded areas in Figs. 2*a* and 2*b*, appear to be smaller for small than for large colonies. It was therefore thought possible that the smallest-colony group, which gained most from spring feeding, gained because its colonies were short of stores. In order to test this, the gain in bees in the colonies within this group which had *more* than 10 lb. spring stores was compared with the gain in bees in the colonies within the same group having 10 lb. or less. The average gains were the same to within 0.2 frame of bees.

The extra net stores consumed by the fed colony compared with its unfed control (not shown in Fig. 2) was fairly constant (just over 5 lb.) for all sizes of colony. The extra spring stores in the fed colony compared with its unfed control colony decreased as the size of the colony increased, from 5 lb. for the smallest-colony group to 0 lb. for the largest-colony group.

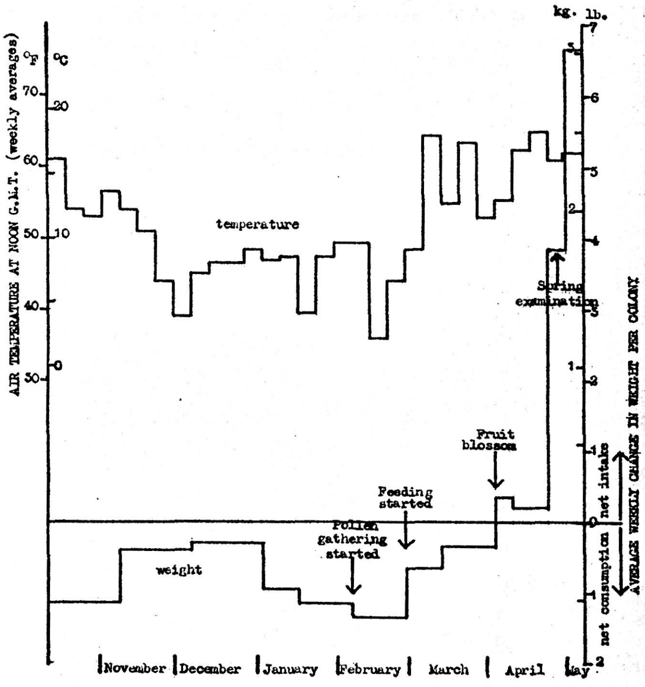

Fig. 3. Average weekly changes in weight of six colonies (lower line) and average air temperature at noon (upper line) at Clevedon, Somerset.

Fig. 3 provides a partial explanation for these observations. It shows the average rate of consumption of stores of six colonies (three pairs) throughout the period of the experiment, together with the air temperature at noon (G.M.T.). Three of the colonies were fed 6½ lb. sugar each in March and April 1948, and three were not fed. The data were supplied by Lieut. Colonel E. C. Brown, and relate to colonies at Clevedon on the southern shore of the Bristol Channel where spring comes early; the white horse chestnut first bloomed on April 25th, and the colonies were examined on April 27th. The significance of Fig. 3 in the present context is that the average net consumption of stores decreased after the end of February, when the temperature began to rise steadily, and that it became zero early in April and was thereafter replaced by a net gain.

The sequence of flowering is fairly uniform throughout the country, and records from a number of Yorkshire beekeepers confirm that in 1948 there was a minor nectar flow, mainly from tree fruit and sycamore (*Acer pseudoplatanus*) for one or in some cases two weeks before the horse chestnut was in full bloom, *i.e.* before the spring examination. It is probable that in most cases comparatively little nectar was available earlier than this.

It therefore seems likely *a* that the amount of stores in the colony a few weeks earlier would in many cases be less than at the spring examination, *b* that the increase in the amount of spring stores with the strength of the colony (Fig. 2) may have been partly due to the ability of the large, but not of the small, colonies to take advantage of a flow just before the examination, *c* that the amount of brood at the spring examination, but not the amount of bees, might be influenced by the first nectar flow (in late spring).

If *b* be true, then the total consumption of honey between the autumn and spring examination may have been considerably more in large than in small colonies. The fact remains however that the beekeeper's average net outlay, in honey and or sugar, necessary to maintain a colony between the autumn and spring examinations, was the same whether the colony covered 5 or 25 frames in spring—surely a valid reason for wintering large colonies.

Water supply. Beekeepers were asked to describe the sources of water which the bees used during the period of the experiment, and to give the approximate distance from the hive. Owners of 106 pairs of colonies were able to give this information. While these records are probably not entirely accurate, it is believed that they give at least a rough idea of the distances from which the bees fetched their water supplies in spring. In order to try to discover whether the benefit of feeding syrup (sugar + water) in spring was related to the carrying of water from the outside the hive, the 106 pairs were divided into two groups as nearly equal in size as possible: group WL consisted of 51 pairs of colonies whose bees were observed to collect water from sources less than 50 yd. (50 m.) from the hives, and group WM consisted of 55 pairs whose bees were observed to collect water only from sources farther away than this. The average distance between the hives and water supply for the two groups were 15 yd. and 130 yd. respectively.

These two groups could not usefully be compared directly with each other, since there was no matching between the colonies in them. They were therefore treated as separate units, and the results which are given in Table 2 for all the pairs together were calculated separately for those in each of these two groups; they are given in Table 3.

The pairs of colonies in the groups WL and WM were distributed with respect to spring strength of the control colony (frames covered by bees) as follows:

No. frames bees (control colony)	5-8	9-11	12-14	15-26	Total
No. pairs in WL	13	12	10	16	51
No. pairs in WM	13	14	12	16	55

Since the two groups were so nearly equally distributed with respect to strength, it is unlikely that the results in Table 3 were biased by this factor.

According to Table 3, the fed colonies in both groups gained in bees and in brood compared with their unfed control colonies. However, while the WM group gained significantly in both bees (1·61 frames) and brood (1·13 frames), the gain in the WL group (0·67 frames covered by bees and 0·75 frames containing brood) was too small to be significant. The average extra net consumption of stores in the fed colony for the WM group was 7·04 lb. honey and is certainly significant; that for the WL group was 2·98 lb. and is possibly significant.

It seems therefore that, unless some unknown factor had affected one group and not the other, the value of the water supplied in the syrup *was* related to the length of journey necessary for fetching water from an external source. If the experiment had been carried out only with the WL pairs of colonies, the results would have suggested that spring feeding had no significant effect on the development of the colony; on the other hand if only the WM pairs had been used, the

TABLE 3

Effect of accessibility of water on the advantage gained by spring-feeding 106 colonies, compared with 106 unfed control colonies

Condition at spring examination		Group WL (51 pairs) Water less than 50 yd.			Group WM (55 pairs) Water 50 yd. or more		
		Mean	S.e. of mean	*v*	Mean	S.e. of mean	*v*
No. frames covered by bees:	Fed colony (F)	13·4	±0·76	0·44	13·5	±0·69	0·38
	Unfed colony (C)	12·7	±0·74	0·41	11·9	±0·59	0·37
	F-C	0·67	±0·54		1·61	±0·40	
No. frames containing brood:	Fed colony (F)	8·7	±0·51	0·42	9·2	±0·40	0·32
	Unfed colony (C)	8·0	±0·46	0·40	8·1	±0·44	0·40
	F-C	0·75	±0·44		1·13	±0·32	
Net stores consumed (as lb. honey):	Fed colony (F)	28·4	±1·63	0·41	31·9	±1·64	0·38
	Unfed colony (C)	25·5	±1·54	0·43	24·9	±1·38	0·41
	F-C	2·98	±1·25		7·04	±1·10	

results would have shown a significant gain in bees and in brood, and in the net stores consumed before spring examination.

Amount of syrup given. The average weight of *sugar* which was fed to the bees (and taken into the hive) was 7·4 lb. (9·2 lb. honey, see Table 1). In 91% of the colonies it was between 5 and 11 lb.; 7 colonies accepted only 3 or 4 lb.; 5 were fed 12-15 lb. because they were in 'late' districts and feeding was continued well into May.

Too few colonies (9) were fed diluted honey instead of sugar syrup to warrant any distinction being made between them and the colonies fed sugar syrup.

Since an overall increased rate of development had been found in the fed colonies, it was important to discover how this was related to the amount of sugar (or honey) fed, which in general increased with the period of time over which the feeding was carried out.

The average weights of sugar fed in the spring syrup to the colonies in the four size-groups shown in Fig. 2 were approximately equal (7·4, 6·9, 8·2 and 7·7 lb. respectively). In general in pairs of colonies where the controls were of a given strength, fed colonies which took *more* syrup than the average gained more in bees and brood than those which took *less* syrup than the average. The number of pairs in each size-group was, however, too small to make a detailed analysis, and in any case there was no matching between fed colonies receiving different amounts of spring syrup.

Method of feeding. The method of feeding was left to the choice of the beekeepers; for 54 colonies a slow (bottle) feeder was used, for 77 a rapid feeder. In both groups the fed colonies gained more in bees and in brood than their unfed control colonies, and the 'net stores consumed' was also higher.

No difference between the effects of rapid and slow feeding was detected, but it must be remembered that the experiment was not designed to test this point, and there was no matching between colonies fed with rapid and slow feeders.

Winter stores. As shown in Table 1, 95% of the colonies were put down to winter with the equivalent of 30 lb. honey or more; 50% had 40 lb. or more. The spring of 1948 was early, and the inspection of the records received suggested that, with a few possible exceptions, colonies were not short of carbohydrate stores at the time of the spring examination.

The average amount of honey left in the hives in the autumn for each of the size-groups is given in Fig. 2. It increased steadily with spring colony strength; but the lowest average (for the 5-8 frame spring colonies) was 37 lb. The effect of spring feeding was not apparently dependent on the amount of winter stores; the result might well have been different had these been inadequate.

With regard to pollen supplies, the same sources of pollen were available to both colonies of a pair, and both were wintered with approximately similar pollen reserves. The only remark which can be made is an observation on the beekeeper rather than on his bees. Only 30% of the colonies were rated as having medium or poor pollen supplies, 70% being considered to have 'good' supplies.

DISCUSSION

The results reported above show that in the spring of 1948, which was a very early one following a mild, open winter, the provision of syrup (1 lb. sugar to 1 pt. water, or 440 g./l. solution) during March and April led to an average increased rate of development of the colonies used, which were probably fairly typical of those owned by good amateur beekeepers in England. Since the fed colonies were stronger than their unfed control colonies in bees as well as brood, they must have been developing more rapidly for at least the last three weeks of the feeding period, and it is likely that the differentiation began earlier than this, and indeed extended over most of the feeding period.

The fact that the benefit of syrup feeding in spring was related to the size of the colony, and probably also to the accessibility of water other than that provided in the syrup, helps to throw some light on the diversity of opinions and results mentioned in the *Introduction*. Information has also been obtained on winter losses and on the *variation* between colonies which constituted the material for the experiment.

Experimental variation. Table 2 shows the amount of variation found in the spring strengths of the colonies in bees and brood, and in calculated 'net stores consumed'. For the first two quantities the coefficient of variation was about 0·3, for both fed colonies and control colonies; for the 'net stores consumed' it was rather higher.

It is of some interest to compare these variations (for colonies not matched in any way) with those in the groups of colonies matched in the autumn in Butler's (1946) experiment. For the 10 control colonies, matched among themselves in autumn, the coefficient of variation was 0·42 for combs covered by bees, 0·32 for brood area and 0·53 for carbohydrate stores (all spring results). The variation seems to have been no less than in the present experiment, in which the colonies were of different strains, in different districts, and estimated by different observers.

Effect of colony size. In the present experiment small colonies (up to 8 frames of bees when the white horse chestnut was in bloom) gained 36% in bees by syrup feeding during March and April; 9 - 14 frame colonies gained about 11% and colonies with more than 14 frames of bees were on the whole unaffected (see Fig. 1). One might therefore expect disagreement as to the value of spring feeding between beekeepers who winter large colonies and those who winter small ones. It should be noted that Butler's (1946) experiments, which showed no gain from spring-feeding syrup of the same concentration as that used in the present experiments, were carried out with rather large colonies (average spring strength 11 - 12 frames of bees).

If this relation between colony size and the effect of spring feeding is true in general, it may not be entirely a coincidence that spring feeding has fallen more and more out of fashion in Britain, particularly among the more progressive and the commercial beekeepers, during the period of increasing popularity of prolific Italian strains. The colony size of prolific Italian bees is probably double that which was usual with indigenous black bees. In the U.S.A., where large colonies of Italian bees are the general rule, spring feeding is not generally practised.

The size of a colony is one of the most important factors in determining its efficiency, and the results shown in Fig. 3 emphasize the increase of efficiency obtained by wintering large colonies instead of small ones. The average 'net stores consumed' between autumn and spring were practically the same (about 25 lb.) for colonies of all spring strengths between 5 and 25 frames of bees. No results were obtained for the *total* stores consumed, which may have varied considerably with the size of the colony. Also, the results given refer to carbohydrate stores only; no information was obtained in the present experiment about the important problem of winter pollen consumption (see Maurizio, 1950).

The amount of honey present at the time of the spring examination increased steadily with the size of the colony

(Fig. 2). This may have been due to the heavier autumn stores, or to a greater spring foraging activity, or to both factors. Whatever its origin, it raises the question already mentioned, whether the gain in bees and brood of the small colonies was in fact due to a real shortage of carbohydrate stores. It is difficult to accept this explanation for two reasons. In the first place the weights of spring stores in the 5 - 8, 9 - 14 and 15 + frame groups differed much less than the amounts of bees and brood in the colonies of these groups. Secondly, within the 5 - 8 frame group, colonies with *more* than 10 lb. spring stores gained as much as colonies with 10 lb. or less.

Further experiments are needed to answer the following important questions :

a Does spring feeding lead to an increased rate of development of small colonies if they have a *very large* excess of stores ?

b Does spring feeding have as great an effect on small colonies in a cold spring, when breeding is more retarded than in 1948 ?

c Is the effect of spring feeding the same on *weak* spring colonies as on *small* but potentially strong spring colonies (such as nuclei with last season's queens and young bees fed with ample pollen in the autumn) ?

Water requirements and spring feeding. The results described in this paper suggest that colonies whose water carriers fetch their loads from a distance gain more from being fed syrup in spring than those whose water carriers have not so far to fly. Dr. Butler has informed me that in his experiments, in which spring feeding produced no effect, water was provided close to the hives, and the bees used it. The absence of benefit in his experiment is therefore consistent with the present results.

It is common knowledge that in a honeybee colony brood cannot be reared on honey and pollen alone, but that water is also needed, and that, especially during the period in spring between the commencement of brood rearing and of the first nectar flow, bees collect and carry to the hive large quantities of water (*e.g.* Park, 1949 ; Wedmore, 1946). What *is* perhaps new in the present results is the practical demonstration, in a large-scale experiment under ordinary beekeeping conditions, that syrup feeding in spring led to a significant gain in bees and brood in colonies relatively far away from their external water supply, but not in colonies relatively near to it. It has been explained under *Results* that this was not due to different strengths of the colonies in the two groups nor, as far as can be ascertained, to some other secondary factor.

However, the next step is to design an experiment to test this point. This has been done by extending the 1948-49 experiment to include sets of *three* matched colonies instead of *two*. The additional colony in each set is being provided with an excess supply of water in the top of the hive during the whole of the period when the second colony is being fed syrup. A record is being kept of the weekly consumption of both syrup and water, and it is hoped to obtain information as to both the variation in the rate of water consumption and the comparative effects of water and syrup feeding in the spring development of the colony.

For the time being we can only say that it seems likely that, for a colony with ample stores, the provision of the *sugar* in the syrup is unimportant, but that the provision of *water* in the syrup is of considerable value to the colony. It should be borne in mind that small colonies (which gained most from spring feeding) can spare relatively fewer bees for foraging than very large colonies (which did not gain from spring feeding) in which temperature regulation of the brood nest is more efficiently conducted. It must also be remembered that excess *sugar* can easily be stored for long periods in the hive, but that excess *water* cannot (see Park, 1949).

When information is available on the relative effects of water and syrup feeding, experiments should be carried out with more dilute sugar syrup than that used in the present experiment. It may be that the most important function of the sugar in the syrup is to make it palatable to the bees so that the water is taken down into the hive. Pure water is not very acceptable to honeybees (Butler, 1940). Butler (1946) fed six colonies with very dilute syrup in spring, using six similar colonies as controls, but with this small number of colonies no effect smaller than 35-50% would be detectable.

According to the present interpretation of the mode of effect of spring feeding, it might be expected that more *concentrated* syrup would be less advantageous. Butler's (1946) results, obtained with syrup containing 2 lb. sugar to 1 pt. water (615 g./l. solution), are interesting in this connection. Nine colonies (matched with those listed in Table 1) were fed 10 lb. sugar in syrup of this concentration. These colonies had less bees and brood than either the 10 unfed colonies or the 9 colonies fed with syrup containing 1 lb. sugar to 1 pt. water. The only result which was above the level of significance was the *reduction* (37%) in the average amount of brood in the colonies fed with concentrated syrup compared with the control colonies.

The excitement of a colony after syrup feeding, which leads to a wastage of energy (and therefore of food), is likely to increase with the concentration of the syrup fed ; it may be that, for any given colony, there is a critical concentration above which the loss of energy due to excitement more than balances the saving of energy resulting from the provision of water. Many more experiments must be done before we understand fully the sequence of events which is set in motion when we pour syrup into the feeders on our hives in spring.

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SUMMARY

1. In spring 1948 experiments were carried out by beekeepers in various parts of England on 131 pairs of colonies which had been matched in the previous autumn and which had adequate winter stores ; one colony of each pair was fed sugar syrup or honey during March and April, and the other left unfed. The spring was a mild open one.

2. The strengths of the two colonies in bees and brood were compared when the white horse chestnut was in bloom,

and the stores also estimated. The fed colonies were significantly ahead of their control colonies, by an average of 1·03 ± 0·30 frames of bees plus 0·89 ± 0·27 frames of brood ; they had consumed only 5·37 ± 0·76 lb. honey extra, although the average amount fed to them in spring was 9·2 lb.

3. The effect of spring feeding on the development of the colonies increased with decreasing (spring) strength, from zero for very large colonies to 36% in bees and 55% in brood for small colonies (8 frames or less).

4. The benefit of spring feeding appeared to depend also upon the distance of the colony from its external water supply, and it seems probable that the water in the syrup is of more value to the bees than the sugar.

5. It is considered likely that the difference of opinion as to the value of spring stimulation is at least partly explained by results 3 and 4 above.

6. Results are also given for the winter and spring losses (colonies which seceded from the experiment), and for the experimental variation between colonies used.

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