J. nat. Rubb. Res., 1(3), 176-186

Relationship of Nectar Flow on Colony Development and Honey Yield of Apis cerana *under* Hevea brasiliensis *in Malaysia*

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Studies conducted in 1985 indicated that clones RRIM 701, RRIM 600 and PR 255 are potential sources of nectar for bees. In all the clones, nectar was available for about one month with the peaks of flow occurring during the second and third weeks of March. The volume of nectar flow of the clones was highly negatively correlated with rainfall. There was no correlation between the volume of nectar and its sugar content, suggesting no preference for any clone by nectar foraging Apis cerana.

The formation of honey cells, brood cells, pollen cells and new honeycomb cells were interrelated. Correlations between brood, pollen, honey and newcomb cells were significantly high in RRIM 701 but there were no correlations between the various cells with RRIM 600 and PR 255. The potential of clones limiting the activities of bees and the bee-keepers are discussed.

Honey production among clones studied was not significantly different. A total of 2.97 kg, 2.13 kg and 1.73 kg of honey per hive was harvested from bee hives under RRIM 701, RRIM 600 and PR 255 respectively. The weight of honey harvested was similar to the ranking of nectar flow.

Various limitations of bee-keeping under rubber are highlighted and some management strategies outlined.

The viability of bee-keeping under rubber, *Hevea brasiliensis*, in Malaysia has not been fully investigated[1]. The success of bee-keeping in the rubber-growing areas of Malaysia depends upon the knowledge of the inter-relationship of the season of rubber nectar flow, the adaptability of the honeybee colonies introduced, and the yield of honey that can be harvested from the existing commercial rubber clones.

The rubber tree is an important source of nectar for honeybees in tropical countries[2,3]. Nectar is usually secreted by the nectaries of young leaves during the refoliation period[4,5]. In Malaysia, it was observed that nectar from rubber is produced from the nectiferous buds, the young leaf axils, the flowers and the nectary glands of trifoliate leaves. It is possible that not all rubber clones produce nectar and no documentation of inter-clonal difference in nectar production is available. Information on volume of nectar and its sugar content can show the potential of clones for bee-keeping.

Although *A. cerana* is known to immigrate and nest in rubber plantations during refoliation, information on colony development within the rubber ecosystem is lacking. Knowledge on the development of several parameters such as brood, queen, pollen, honey and newcomb cells wll be useful in outlining management strategies of bee-keeping under rubber.

This paper reports some investigations and assessments of the relationship of nectar on the development of *A. cerana* colonies and the honey yield under clones of RRIM 701, RRIM 600 and PR 255.

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MATERIALS AND METHODS

In 1985, three clones of rubber, RRIM 701, RRIM 600 and PR 255 of about the same age (twelve-year-old) from three different locations of about 0.4 ha each within the Rubber Research Institute of Malaysia Experiment Station in Sungai Buloh were selected for the experiment. Four bee colonies, each having approximately 10 000 bees were spaced 50 m apart. The bee colonies were introduced in late February 1985 and food was supplemented in the form of 50% sugar solution during routine inspection prior to refoliation. Three experiments were carried out concurrently during the season of nectar flow.

Survey of Nectar from Extra-floral Nectaries and Sugar Content.

During the early period of refoliation, new flushes of leaves of the same age from clones RRIM 701, RRIM 600 and PR 255 were tagged in order to monitor the production of nectar and the sugar content. Ten trifoliate leaves from each of ten trees in the lowest branch per clone were monitored. Micro-capillary pipettes and a refractometer were used to measure the volume of the nectar droplet and the sugar content respectively. Sampling was carried out at about 10.00 a.m. at which time many bees were seen collecting nectar from nectary glands of trifoliate leaves *(Figure 1)*.

Colony Development.

At the first sign of nectar flow indicated by the increase of foraging activities and the frequent visit of bees to the nectar droplets *(Figure 2)*, individual frames of honeycomb cells were cut to an approximate size of 10 × 12.5 cm. Six such frames were introduced into each hive. Various parameters (mean numbers of cells filled with brood, pollen, honey, queen larvae and new cells per hive) were recorded weekly until the period of nectar flow commenced.

Assessment of Honey Yield.

The same rubber clones were assessed for their honey yield. Rubber honey was harvested twice (March 15 and April 30) during the season. The honey was harvested by the destructive method: honeycomb with honey was cut using a knife and the remaining comb with eggs and larvae were re-attached to the frames.

RESULTS AND DISCUSSION

Survey of Nectar from Extra-floral Nectaries and Sugar Content

Nectar generally is at maximum production when young leaves of rubber clones are changing colour from bronze to light green. During the period of study, refoliation of rubber within each clone was observed to be staggered. In all clones studied, refoliation occurred during the middle of February and leaves ceased producing nectar in late March.

The analysis of nectar flow indicated that the clones RRIM 701, RRIM 600 and PR 255 did not show any significant difference in the amount of nectar during the season of nectar flow *(Table 1)*. However, mean of nectar per leaflet showed that RRIM 701 was having better nectar flow (higher volume of nectar droplets) than the other two clones. The peak of nectar flow occurred during the second and third weeks of March for all the three clones *(Figure 3* and *Table 2)*. The study revealed that the volume (μlitres) of nectar was highly negatively correlated with the amount of rainfall *(Figure 4)*. It was evident that rain washed off the nectar from the leaflets. Probably, rain reduced the sugar content of nectar secreted but not as much as by diluting the sugar content as by the increase of uptake of water through the translocative processes of the plant brought about by the effect of the turgor pressure. In general, there was a tendency for the correlation between volume of nectar and sugar content to be negative for all clones, but there was no evidence to support that the increase in volume of nectar would reduce the amount of sugar *(Table 3)*.

Colony Development

The formation of cells such as honey cell *(Table 4)*, brood cell *(Table 5)*, pollen cell *(Table 6)* and new cell *(Table 7)* were interrelated to each other. The correlations between brood cell, pollen cell, honey cell and new cell were significant in RRIM 701 *(Table 8)*. No

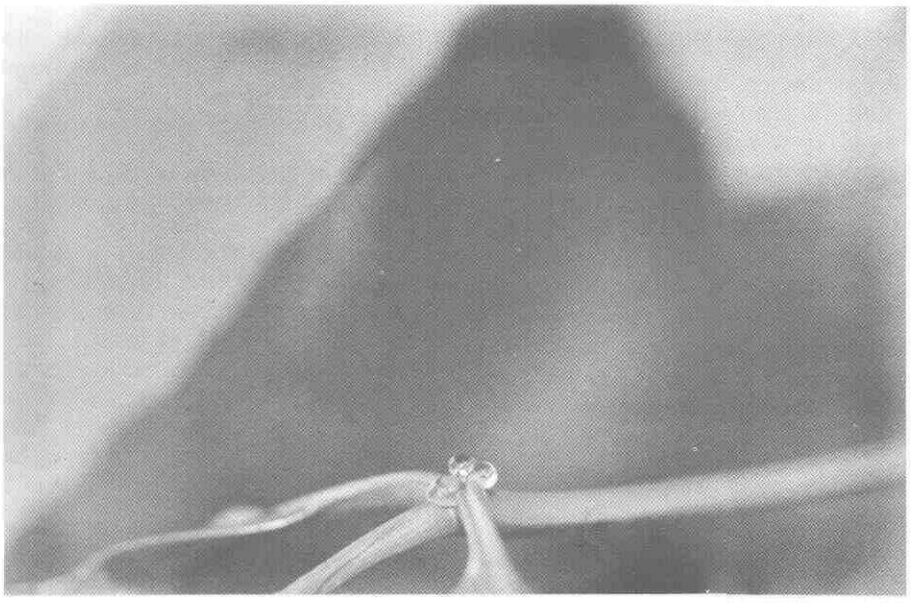

Figure 1. Three droplets of nectar from three glands of a trifoliate leaf.

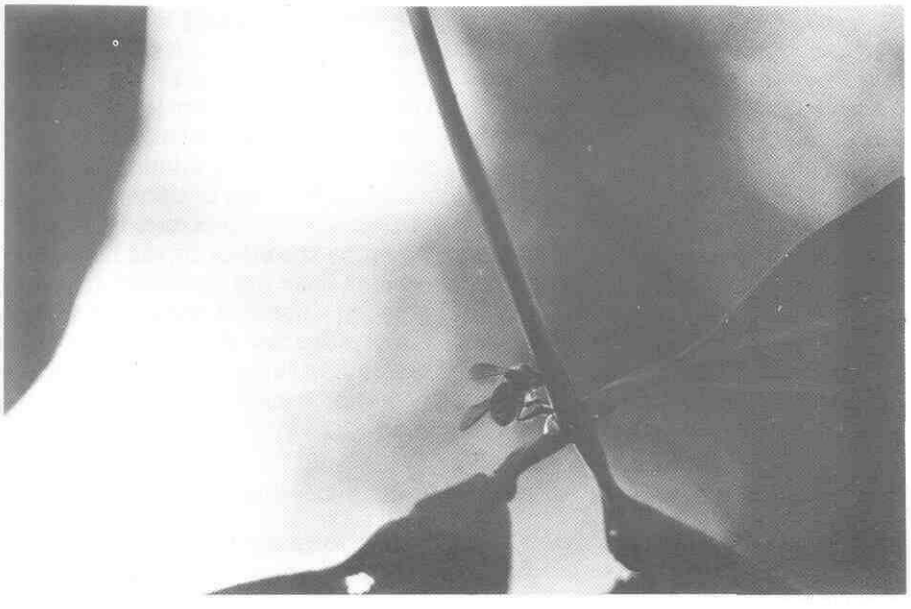

Figure 2. Apis cerana *collecting nectar from rubber leaf.*

TABLE 1. VOLUME AND SUGAR CONTENT OF NECTAR FROM EXTRA-FLORAL NECTARIES OF SELECTED CLONES OF RUBBER

Date	RRIM 701			RRIM 600			PR 255		
	Nectar per leaflet (μlitre)		Mean sugar content, $\bar{Y}$	Nectar per leaflet (μlitre)		Mean sugar content, $\bar{Y}$	Nectar per leaflet (μlitre)		Mean sugar content, $\bar{Y}$
	$\bar{X}$	Max	(%)	$\bar{X}$	Max	(%)	$\bar{X}$	Max	(%)
11.3.85	1.85	2.00	6.80	2.00	3.00	7.90	1.75	2.50	8.20
13.3.85	4.20	9.00	5.80	2.60	9.00	7.50	2.25	5.00	7.50
16.3.85	3.50	6.00	3.30	3.70	4.50	4.00	3.55	4.00	2.00
19.3.85	4.80	6.00	5.50	4.40	6.50	6.00	4.30	5.50	6.00
22.3.85	3.20	4.00	4.50	3.15	4.50	3.00	3.65	5.50	2.30
26.3.85	3.10	4.00	3.30	2.45	3.50	3.10	2.75	3.50	2.00
28.3.85	1.70	2.50	6.50	1.95	3.00	7.70	2.40	3.00	7.30

Standard error of date (D) = 0.22
Standard error of clone (C) = 0.14
Standard error of D × C = 0.38

$\bar{X}$ is the volume of nectar from a total of ten leaflets from ten trees.
It rained in the afternoon and night on 16, 22 and 26 March 1985.

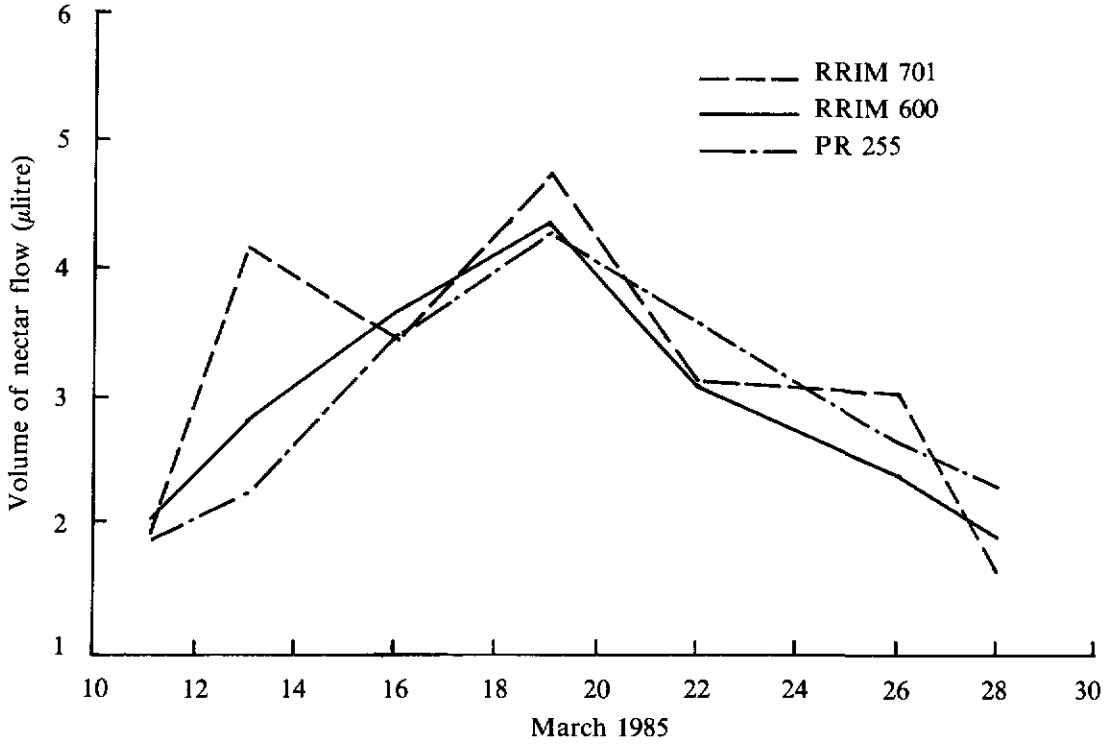

Figure 3. Average volume of flow of nectar from clones RRIM 701, RRIM 600 and PR 255 (11–28 March 1985).

TABLE 2. ANALYSIS OF VARIANCE OF VOLUME OF NECTAR PER LEAFLET OF RRIM 701, RRIM 600 AND PR 255

Source of variation	Degrees of freedom	Mean squares
Date (D)	6	25.05***
Clone (C)	2	1.86
D × C	12	2.00
Error	189	1.43
Mean = 3.02		
S.D. = 1.20		
C.V. (%) = 39.58		

correlation existed between the development of new cell and brood cell in clone RRIM 600 and in clone PR 255. Relating this to the nectar flow, correlation between the development of cells in the comb might be caused by the abundance of food in the area. For example, high association among the cells in RRIM 701 might be related to high volume of nectar flow, and less association among the cells in RRIM 600 and PR 255 might be caused by low nectar flow.

The analysis of variance indicated that there were significant differences among the interaction effect of time of sampling and clone during the formation of cells *(Table 9)*. This indicates that during the refoliation period, the bees in each clone actively work to form honey cells, brood cells, pollen cells and new cells. The activities, however, were limited by the potential of each clone to produce nectar and pollen sources.

Formation of new cells. Formation of new cells showed an increasing trend in all the three rubber clones even though the rates might be

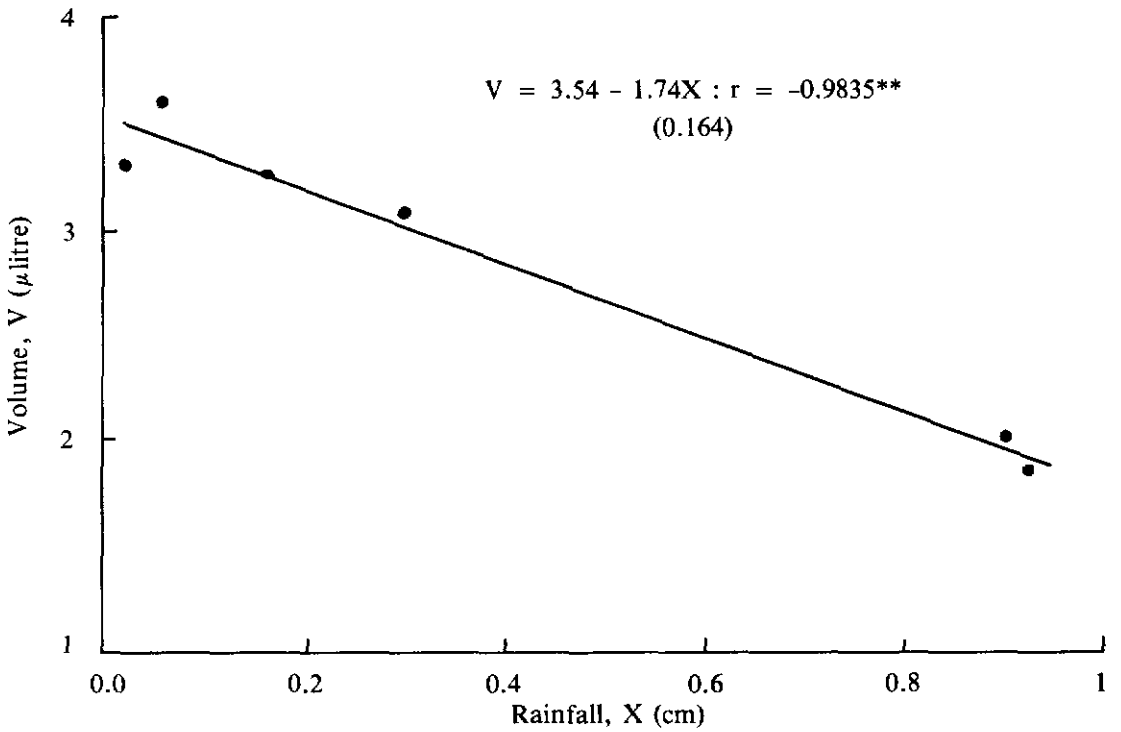

Figure 4. Correlation between volume of nectar and rainfall.

TABLE 3. CORRELATION BETWEEN VOLUME OF NECTAR AND SUGAR CONTENT OF RRIM 701, RRIM 600 AND PR 255

Clone	Correlation of volume of nectar (μlitre) and sugar content (%)
RRIM 701	$-0.35^{N.S.}$
RRIM 600	$-0.44^{N.S.}$
PR 255	$-0.55^{P<0.1}$

TABLE 4. DEVELOPMENT OF HONEY CELLS OF *APIS CERANA* COLONIES UNDER RRIM 701, RRIM 600 AND PR 255

Date	Mean number of honey cells per hive RRIM 701	RRIM 600	PR 255
5.3.85	1 020.0	455.0	0.0
11.3.85	1 145.0	250.0	0.0
17.3.85	835.0	473.0	535.0
23.3.85	558.0	0.0	0.0

Standard error of date (D) = 4.0
Standard error of clone (C) = 3.5
Standard error of D × C = 7.0

different *(Figure 5)*. There was high negative correlation between formation of new cells and pollen cells and honey cell formation in RRIM 701 and RRIM 600 *(Table 8)*. Since harvesting of honey was carried out on 15 March *(Table 10* and *Figure 5)*, worker bees were directed to make new cells rather than collect honey and pollen. Thus, one expects a reduction in the formation of pollen and honey cells during this period.

New cells and brood cells in RRIM 701 were highly negatively correlated, but there was no

TABLE 5. DEVELOPMENT OF BROOD CELLS OF *APIS CERANA* COLONIES UNDER RRIM 701, RRIM 600 AND PR 255

Date	Mean number of brood cells per hive		
	RRIM 701	RRIM 600	PR 255
5.3.85	1 428.0	1 020.0	1 595.0
11.3.85	953.0	2 323.0	2 980.0
17.3.85	493.0	1 550.0	2 600.0
23.3.85	36.0	315.0	170.0

Standard error of date (D) = 134.0
Standard error of clone (C) = 11.6
Standard error of D × C = 23.1

TABLE 6. DEVELOPMENT OF POLLEN CELLS OF *APIS CERANA* COLONIES UNDER RRIM 701, RRIM 600 AND PR 255

Date	Mean number of pollen cells per hive		
	RRIM 701	RRIM 600	PR 255
5.3.85	104.0	80.0	200.0
11.3.85	128.0	63.0	45.0
17.3.85	20.0	58.0	40.0
23.3.85	0.0	5.0	0.0

Standard error of date (D) = 2.0
Standard error of clone (C) = 1.7
Standard error of D × C = 3.4

TABLE 7. DEVELOPMENT OF NEW COMB CELLS OF *APIS CERANA* COLONIES UNDER RRIM 701, RRIM 600 AND PR 255

Date	Mean number of new comb cells per hive		
	RRIM 701	RRIM 600	PR 255
5.3.85	1 615.0	690.0	2 430.0
11.3.85	1 840.0	1 905.0	2 990.0
17.3.85	2 125.0	2 318.0	3 500.0
23.3.85	3 350.0	2 373.0	3 500.0

Standard error of date (D) = 19.2
Standard error of clone (C) = 16.7
Standard error of D × C = 33.3

correlation at all in RRIM 600 and PR 255 *(Table 8)*. Probably, the high nectar flow in RRIM 701 and low nectar flow in RRIM 600 and PR 255 were the indirect causes of this situation.

Formation of pollen cells. In general, the decrease in the formation of pollen cells was observed in all three clones as refoliation progressed *(Figure 6)*. Though the identity of pollen was not determined, observations indicated that bees also visited rubber flowers. That most of the pollen stored belongs to rubber clones needs further confirmation.

Formation of brood cells. Brood cell formation by bees located under RRIM 701 had a

TABLE 8. CORRELATION BETWEEN BROOD CELLS, POLLEN CELLS, HONEY CELLS AND NEW CELLS OF *APIS CERANA* COLONIES UNDER RRIM 701, RRIM 600 AND PR 255 IN THE RUBBER RESEARCH INSTITUTE OF MALAYSIA EXPERIMENT STATION

Type of cell	Clone		
	RRIM 701	RRIM 600	PR 255
Brood and pollen	0.861***	0.602**	0.356^{NS}
Brood and honey	0.850***	$0.365^{P<0.1}$	$0.404^{P<0.1}$
Honey and pollen	0.941***	0.827***	-0.236^{NS}
Brood and new	−0.906***	-0.009^{NS}	-0.163^{NS}
New and pollen	−0.800***	−0.687**	−0.910***
New and honey	−0.914***	−0.497*	−0.510*

TABLE 9. ANALYSIS OF VARIANCE OF NUMBER OF CELLS (IN THOUSAND) OF *APIS CERANA*

Source of variation	Degrees of freedom	Mean square			
		Brood	Pollen	Honey	New comb
Date (D)	3	7.7939***	0.0352***	0.3908***	4.8579***
Clone (C)	2	4.9195***	0.0016***	2.5567***	6.8734***
D × C	6	1.4087***	0.0079***	0.1781***	0.5141***
Error	36	0.0021	0.0005	0.0002	0.0044
	Mean	1.2890	0.0620	0.4360	2.3860
	S.D.	0.0463	0.0069	0.0140	0.0667
	C.V. (%)	3.5900	11.1300	3.2100	2.7900

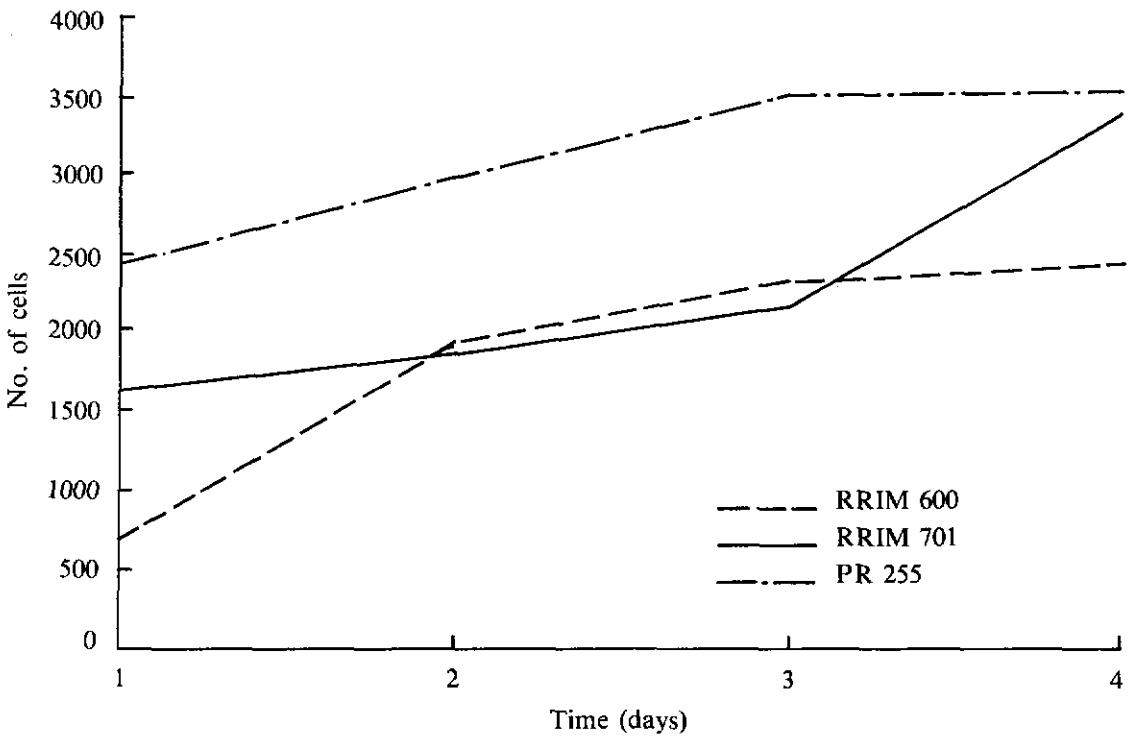

Figure 5. Formation of new cells under clones RRIM 600, RRIM 701 and PR 255.

decreasing trend as time increased, but the bees in the other two clones indicated quadratic trends as the time increased *(Figure 7)*. The trend for brood cell formation in RRIM 600 and PR 255 was similar to the trend of nectar flow in the respective clones. One might believe that the strong association might occur between clones with low nectar flow, but this might not

TABLE 10. YIELD OF HONEY FROM CLONES RRIM 701, RRIM 600 AND PR 255

Date of harvest	Mean[a] weight of honey per hive (kg) RRIM 701	RRIM 600	PR 255
15.3.85	1.67	1.08	1.00
30.4.85	1.30	1.05	0.73

Standard error of clone = 0.226
Standard error of date = 0.369
Coefficient of variability (%) = 56.27

[a]Mean of four hives per treatment harvested at different dates.

TABLE 11. ANALYSIS OF VARIANCE OF WEIGHT OF HONEY HARVESTED FROM BEE COLONIES UNDER RRIM 701, RRIM 600 AND PR 255

Source of variation	Degrees of freedom	Mean squares
Clone (C)	2	$0.418^{N.S.}$
Date of harvest (D)	1	$1.063^{N.S.}$
C × D	2	$0.056^{N.S.}$
Error	18	0.408

Mean = 1.135
S.D. = 0.639
C.V. (%) = 56.27

happen in clones with high nectar flow as indicated by RRIM 701.

Honey Yield

Honey production under the three clones did not show any significant difference, even though clone RRIM 701 seemed to be a potential clone *(Table 10)*. High variability in the production of honey among the bee hives under the three clones (C.V. = 56.27%) made it difficult to detect clone effect and harvesting time effect *(Table 11)*.

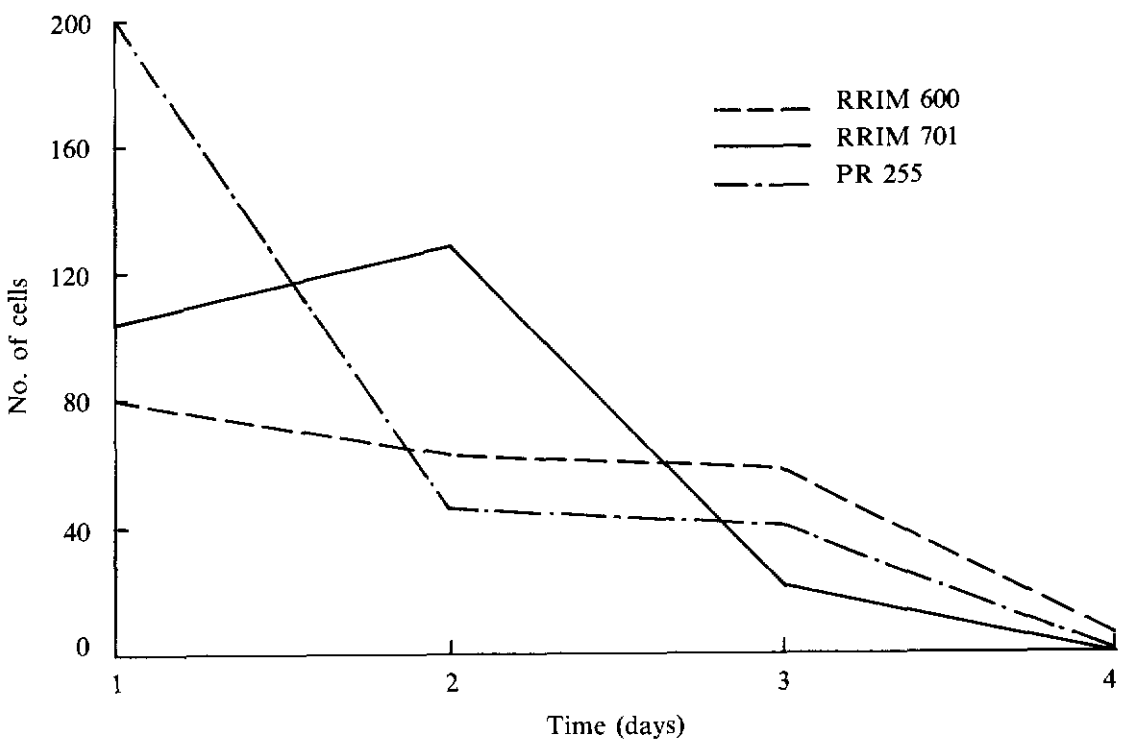

Figure 6. Formation of pollen cells under clones RRIM 600, RRIM 701 and PR 255.

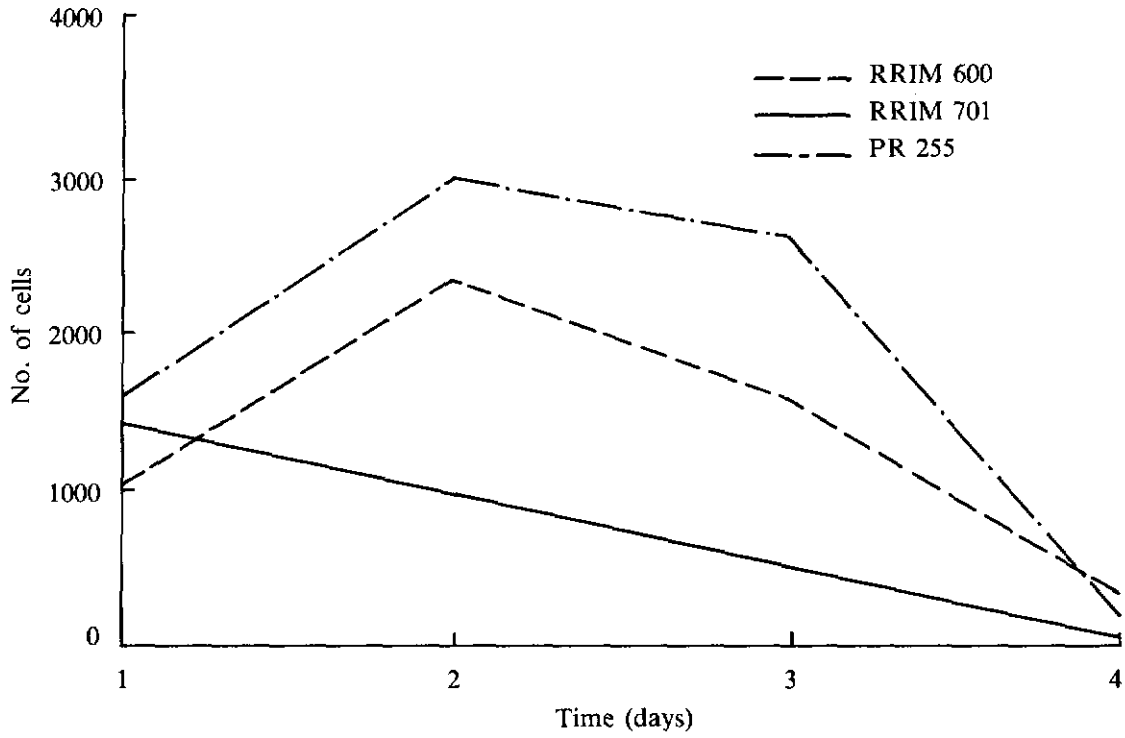

Figure 7. Formation of brood cells under clones RRIM 600, RRIM 701 and PR 255.

A total of 2.97 kg, 2.13 kg and 1.73 kg of honey per hive was produced from clones RRIM 701, RRIM 600 and PR 255, respectively during the trial. In this experiment, the ranking of nectar flow was similar to that of the weight of honey collected *(Table 10* and *Table 1)*.

CONCLUSION

It is felt that there are many possibilities which directly or indirectly affect the honey yield in the experiments and its recording. They could be attributed to:

- rain washing off nectar
- robbing of honey by bees from among colonies
- foraging bees returning to wrong hives due to navigation difficulties as canopy of clones increased. (This leads to fighting and killing of worker bees within and between clonal areas.)
- competition for nectar between bees and other nectiferous insects within clones
- tapping, leaf diseases and routine management practices which could affect nectar secreting ability of clones
- staggered refoliation within clones.

During the course of the study, it was observed that when nectar evaporated, residues of nectar were smeared over leaves (probably brought about by other competing insects) and occasionally the leaf-parasitic fungus, *Oidium sp* was found to germinate on this. Preliminary studies on germination of *Oidium sp* spores under these conditions indicate that competing insects could be the vectors for *Oidium sp* disease. Nevertheless, *Oidium* disease was not severe in all the clones studied and there was no leaf fall. Perhaps the honeybees had deprived other insects from competing for the nectar. The hypothesis of using honeybees as a biological

control agent (through competition of resource) of the rubber pests and diseases in Malaysia need to be further investigated.

It was also observed that some hives started producing new queens around the third week of March from colonies under every clone studied. Either these queen cells should be removed to prevent division of colonies, or the bee-keepers could multiply their colonies, or the transferring their hives to other areas rich in nectar and pollen sources for another harvest. When rubber leaves turned dark green (nectar flow commenced), newly established colonies should be shifted out of rubber plantations.

Pollen and nectar of shade-tolerant weeds improved the development of colony. Therefore, it was apparent that weed control operations should not be carried out during the introduction of hives under rubber.

The different amounts of honey harvested correspond to the potential of clones. Because of navigation difficulties as canopy size of clones increased during the nectar flow, further investigations on stocking rate adjustments need to be carried out.

The price of honey during the period studied was about 20 ringgit per kilogramme. Our studies revealed that in a limited area of about 0.4 ha in which the bees are spaced, the honey harvested from under RRIM 701, RRIM 600 and PR 255 were 11.88 kg, 8.52 kg and 6.92 kg respectively. On the basis of having four hives per 0.4 ha under RRIM 701, RRIM 600 and PR 255, bee-keeping could provide respectively approximate income of $237, $170, $138 per month.

More work is also needed to improve the present yield of honey from the clones studied. In view of the viability of bee-keeping under rubber, the interrelationship between weed control, bee-keeping, livestock husbandary and disease control should be considered to emulate the success of the cattle-clover- and bee-keeping industry in western countries.

ACKNOWLEDGEMENT

The author wishes to express his deep appreciation to Dr C.K. John and Dr Tan Ah Moy for their support and encouragement in the preparation of this paper. Thanks are also due to Encik Abd. Aziz Alias and Puan Zakiah Yatim for support in the field work and typing of the manuscript respectively.

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