Preference of Castor varieties for feeding and oviposition by the Leafhopper, *Empoasca flavescens* (F.) (Homoptera, Jassidae) with particular reference to its Honeydew excretion

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(*With two text-figures*)

Seshadri & Seshu (1956) reported differential feeding injury on certain varieties of castor (*Ricinus communis* L.) inflicted by the leafhopper, *Empoasca flavescens* (F.). Further preliminary observations were made by Dorairaj *et al.* (1963) and Jayaraj & Basheer (1964) on castor resistance to this insect. Detailed investigations were made by the author (Jayaraj 1966, 1967a) into the possibility of reducing leafhopper damage through the use of certain specific castor varieties in a study over three seasons (1961-1964) and many sowing periods. In exploring the mechanisms of such resistance and susceptibility in these varieties, the preference-nonpreference component was noted to play an important role. The present observations were, therefore, initiated to study the preference of the leafhopper toward different varieties for feeding and oviposition and toward leaves of different ages in the varieties. The feeding preference was further studied in an indirect way by assessing the rate of honeydew excretion.

MATERIALS AND METHODS

The observations were made under insectary conditions with temperature ranging from 21 to 24°C., humidity 80%, and sufficient artificial lighting. Preference for oviposition was studied in respect of four castor varieties, viz., Dominica (susceptible), C3. Pakistan (tolerant), R.C. 1098 Baker (resistant), and R.C. 1096 Coonoor (resistant), in large wire mesh cages. Four plants, one of each variety, were caged together and 50 adult jassids allowed to oviposit in them over a period of 72 hours.

At the end of this period, the adults were killed by ether fumes, and the plants removed and separately caged. The number of nymphs which hatched out in each case was taken as the indication for the number of eggs laid by the leafhoppers. Since the egg stage of the jassid lasts about eight days (Jayaraj & Basheer, 1964), nymphal counts were commenced from the eighth day of the experiment and continued up to the 12th day.

Preference for feeding was studied in a similar manner by introducing fifty freshly hatched nymphs into the cage. The number of nymphs found feeding on the plants was considered as having been attracted by the varieties. The preference of the leafhopper for leaves of different ages was observed under field conditions with respect to the 20 varieties mentioned in Table 2. Weekly counts of leafhopper population, both nymph and adult, were made during the early hours of the morning from 6 a.m. to 8 a.m. with reference to three leaves in each plant selected from the top, middle, and bottom of the main shoot. Thus in all, 27 leaves in nine plants, three in each replication, were examined for each variety at one time. The observations lasted for a total period ranging from 56 weeks in early-maturing varieties to 66 weeks in late types in two seasons, 1962-63 and 1963-64.

Honeydew experiments : The preference of the leafhopper for the four varieties was also tested by observing the frequency of honeydew excretion as an indication of the feeding efficiency. A small plastic cage made by placing in juxtaposition two circular, colourless and transparent plastic dishes held in position by means of rubber bands was used for the purpose. One leaf lobe was inserted into the cage at a certain marked position and a single leafhopper introduced at a time and allowed to feed for 24 hours. The position of the leaf lobe inside the cage was shifted once in 6 hours so as to avoid overlapping of the honeydew droplets and to facilitate easy counting. Data were gathered separately for males, females, and first instar nymphs in six replications.

The feeding efficiency of the first instar nymph on the four varieties at different times of the day was studied in another experiment by shifting the leaf lobe position once in two hours, commencing from 6 a.m. When shifting the leaf position in the night, minimum light was used for a short time without disturbing the feeding nymph. This experiment was replicated three times.

In assessing the effect of different colours of light on the jassid feeding, cages made out of red, blue, green, yellow, and colourless plastic dishes were used under fluorescent lighting. The first instar nymph was allowed to feed for six hours and the number of honeydew droplets counted. In this experiment the same four varieties were used in four replications.

Results

1. Preference of the jassid for castor varieties for oviposition and feeding

The number of nymphs hatched out from each plant was considered as an index of the preference for oviposition. The results are given below :

Table 1

Preference of Castor varieties for Oviposition and Feeding

Variety	No. of nymphs hatched out from each plant (Mean of 8 observations)	No. of nymphs attracted to each plant for feeding (Mean of 10 observations)
1. DOMINICA (Susceptible)	47·5±9·9	19·8±0·8
2. C3. PAKISTAN (Tolerant)	33·0±3·2	15·7±1·3
3. R.C. 1098 BAKER (Resistant)	14·1±2·5	4·6±0·8
4. R.C. 1096 COONOOR (Resistant)	10·4±2·4	5·5±0·7
Critical difference (P=0.05)	16·0	3·0

The susceptible and tolerant varieties were the most preferred for oviposition and feeding. While these two varieties were preferred alike for oviposition, the susceptible variety attracted significantly more nymphs for feeding.

2. Preference for leaves of different ages in castor

The mean population data of the insect on leaves of different maturity of 20 castor varieties observed during 1962-63 and 1963-64 seasons under field conditions are furnished below.

It may be noted from the Table that the jassid population varied significantly in the different varieties as also on the leaves of three ages. The middle leaf harboured the maximum number with a mean of 25·9 followed by the bottom leaf which had a mean population of 20·6. The top leaf had only a mean population of 4·8 jassids. However, when considering individual varieties, the preference of the insect for the varieties varied in respect of the age of the leaves. In both the bottom and middle leaves the varieties differed among themselves very much in the jassid population while most of the varieties behaved alike in the population on the top leaf. The top leaf therefore, cannot serve as a sound

basis for the evaluation of castor varietal resistance. In any case, the analysis of the population data leaves no doubt that the preference of the

TABLE 2

COMPARISON OF JASSID INCIDENCE ON LEAVES OF THREE AGES IN CASTOR VARIETIES

Variety	Jassid population			Mean
	Bottom leaf	Middle leaf	Top leaf	
Resistant				
1. R.C. 1098 Baker ..	3·3	4·5	1·6	3·1
2. R.C. 1094 Cimmerron ..	7·6	10·1	3·0	6·9
3. R.C. 1096 Coonoor ..	8·8	11·3	2·6	7·5
Intermediate (Tolerant)				
Group I				
4. R.C. 1077 South Africa ..	12·6	19·9	5·0	12·5
5. Mauthner's Dwarf ..	11·0	21·1	8·3	13·5
6. R.C. 1095 U.S. 74 ..	16·7	20·0	3·7	13·5
7. R.C. 552/1 Nagpur ..	13·5	20·4	4·8	12·9
Group II				
8. R.C. 817 Koilpatti ..	18·7	18·2	3·1	13·3
9. R.C. 826 Russia ..	22·2	18·2	2·6	14·3
10. E.B. 26/1 M.P. ..	23·3	18·3	2·5	14·7
11. T.M.V. 1 ..	17·2	29·4	6·0	17·5
Group III				
12. C3. Pakistan ..	28·6	28·2	3·8	20·2
13. R.C. 488 Egypt ..	27·6	29·3	4·7	20·5
14. R.C. 842 Cuddapah ..	25·6	26·7	4·4	18·9
15. T.M.V. 3 ..	42·3	44·7	5·6	30·9
16. Co. 1 ..	31·6	33·6	4·7	23·3
17. T.M.V. 2 ..	44·3	64·0	6·7	38·3
Susceptible				
18. R.C. 1092 Italy ..	14·5	20·8	6·8	14·0
19. Israel M.E. ..	17·7	33·5	6·6	19·3
Highly Susceptible				
20. Dominica ..	25·0	44·9	10·2	26·7
Mean ..	20·6	25·9	4·8	

Difference between varieties significant at the 1% probability level. C.D. (P=0·05) 2·8.
Difference between leaves significant at the 1% probability level. C.D. (P=0·05) 1·1.
Interaction between varieties and leaves significant at the 1% level. C.D. (P=0·05) 5·0.

jassid is for the susceptible and tolerant varieties. The susceptible variety, Dominica, and tolerant varieties like T.M.V. 2 and T.M.V. 3 were preferred to resistant varieties like Baker and Cimmerron.

3. Honeydew excretion as an index of feeding preference

(i) *Excretion of jassid nymph and male and female adults fed on four varieties*

The excretion of the leafhopper, in general, is directly related to the intake of plant sap. Therefore, the number of honeydew droplets excreted by the insect in unit time when fed on different castor varieties is considered as an index for its feeding preference. This assumption is further based on the earlier findings of Maxwell & Painter (1959) who reported the possibility of using the rate of honeydew deposition to measure the degree of resistance of host plants, the rate of ingestion of plant material, and to serve as a crude measure of the metabolic activity of the insect. The honeydew excretion of the nymph and male and female adults was compared and the data illustrated in Fig. 1.

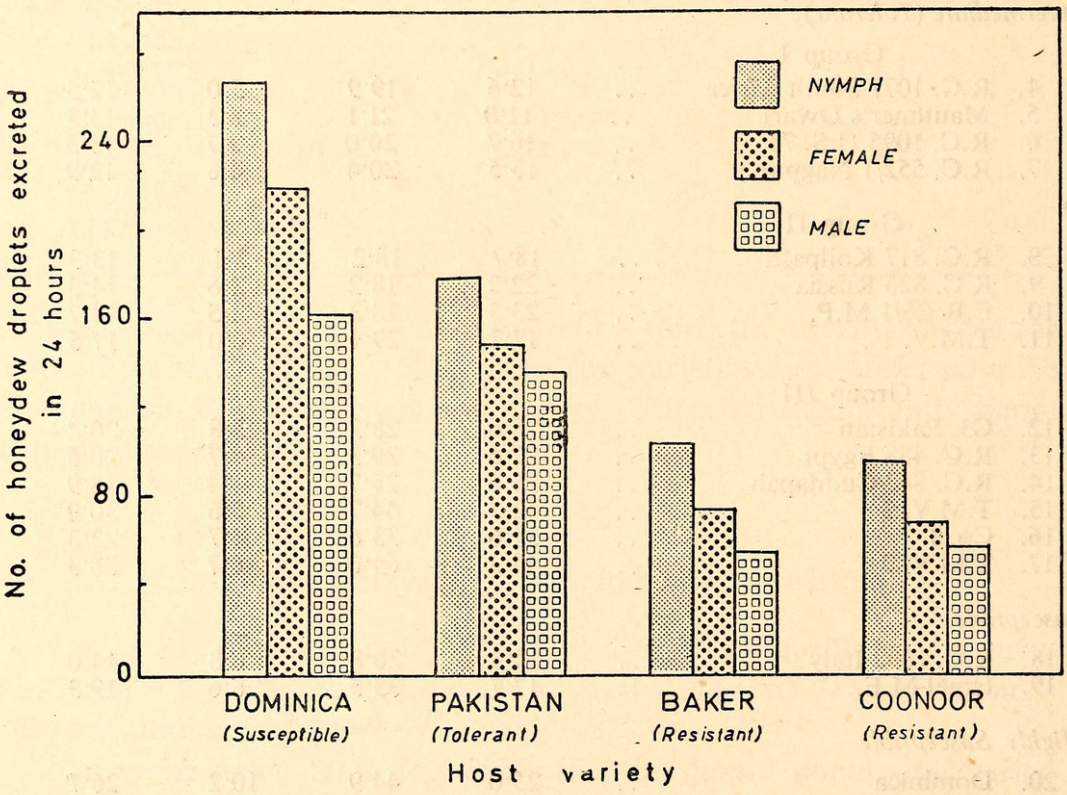

Fig. 1. Honeydew excretion of jassid nymph, male and female adults fed on four castor varieties.

The results show the markedly higher level of excretion of the leafhopper when fed on the susceptible and tolerant varieties than when fed on the resistant ones. Irrespective of the stage or sex of the insect, the jassid excreted on an average 217·8 droplets in a day when fed on Dominica variety and 155·3 on Pakistan variety as against only 75·9 and 69·6 on the resistant Baker and Coonoor varieties respectively. Nymphs caused maximum damage excreting 161·8 honeydew droplets

followed by female (126·9) and male (100·3) adults. The feeding and excretory activity of both the sexes were statistically alike when fed on the tolerant and resistant varieties, while the female excreted significantly more than the male when fed on the susceptible variety.

(ii) *Influence of colour on excretion*

Colour affected the honeydew excretion of this leafhopper. Jassids confined in transparent plastic cages of different colours reacted differently in respect of feeding and honeydew excretion. The data of honeydew drops excreted by first instar nymphs are presented in Table 3

TABLE 3

EFFECT OF DIFFERENT COLOURS ON THE RATE OF HONEYDEW EXCRETION LEAFHOPPER NYMPHS FED ON FOUR CASTOR VARIETIES

Variety	No. of honeydew droplets excreted by a first instar nymph in six hours (Mean of four observations)					
	White	Red	Blue	Green	Yellow	Mean
1. **Dominica** (Susceptible) ..	72·3	10·3	48·0	67·8	18·3	43·3
2. **C3. Pakistan** (Tolerant) ..	60·5	10·8	47·8	64·5	21·5	41·0
3. **R.C. 1098 Baker** (Resistant) ..	34·0	9·0	29·0	29·0	13·5	22·9
4. **R.C. 1096 Coonoor** (Resistant) ..	24·0	8·5	35·0	35·0	13·8	23·3
Mean ..	47·7	9·6	39·9	49·1	16·8	

Difference between varieties significant at the 1% probability level. C.D. (P=0·05) 6·5.

Difference between colours significant at the 1% probability level. C.D. (P=0·05) 22·9.

Interaction between varieties and colours significant at the 1% probability level. C.D. (P=0·05) 14·5.

Normal feeding activity and excretion were observed on exposure to green, white, and blue lights. Marked differences in the number of honeydew drops excreted by the leafhopper fed on the susceptible and tolerant varieties on the one hand and on the resistant varieties on the other were noticeable only under these colours. Very low honeydew deposition was noted in yellow and red lights and all the varieties gave

like results. Thus, besides indicating the effect of colour on the jassid excretion, this experiment also confirmed the preference of the insect for the susceptible and tolerant varieties in preference to the resistant varieties.

(iii) *Honeydew excretion at different times of the day*

The feeding activity of the leafhopper fluctuated at different times of the day. To estimate this, honeydew deposition by first instar nymphs fed on four castor varieties was observed at intervals of two hours. The results are illustrated in Figure 2.

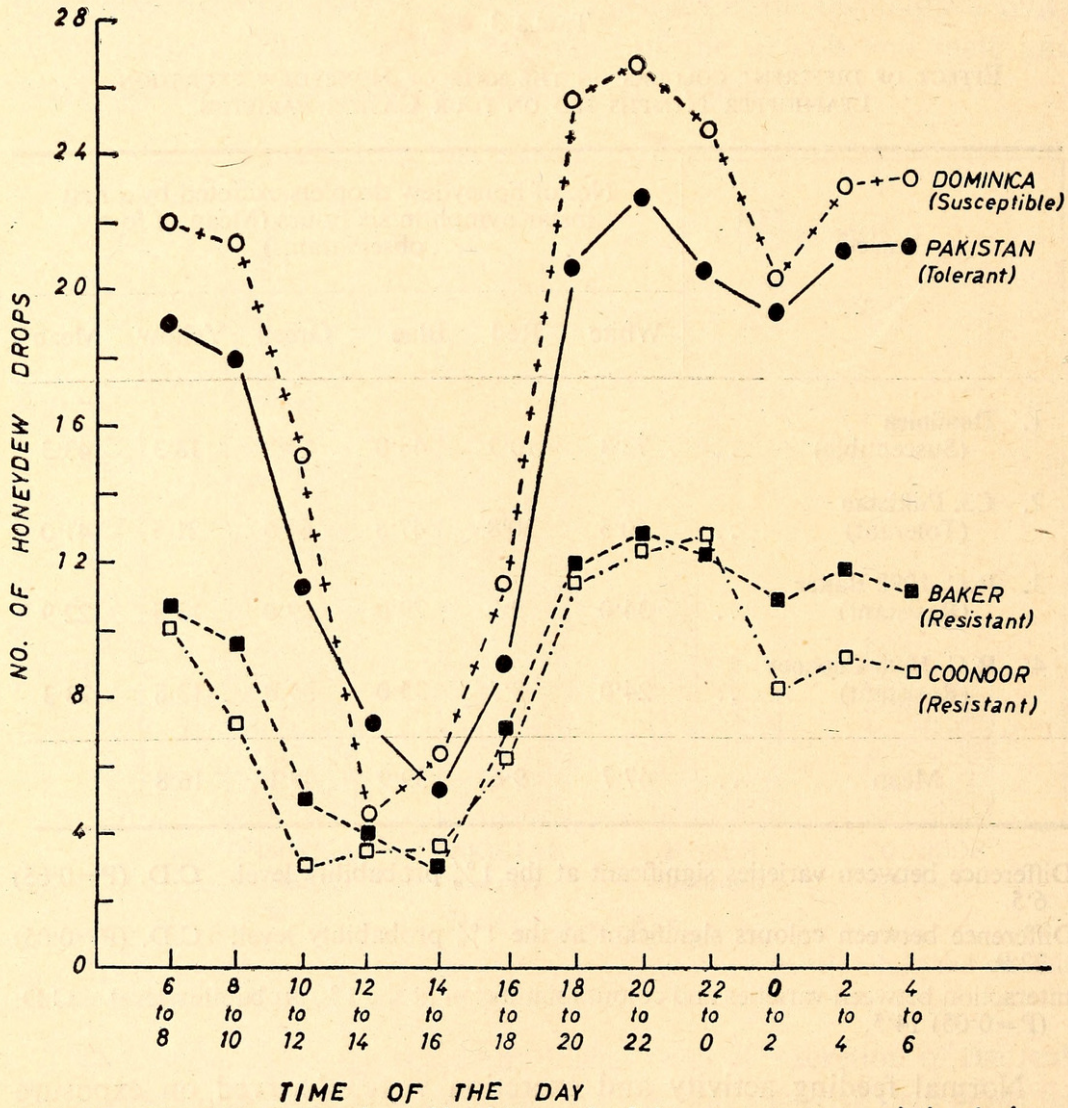

Fig. 2. Honeydew excretion of jassid nymphs fed on four castor varieties during different times of the day.

As in the previous experiments the number of honeydew droplets excreted by the leafhopper was significantly higher when fed on the susceptible and tolerant varieties than when fed on the resistant varieties.

Excretion was markedly more during the night than during the day—100·2 droplets were excreted by a jassid nymph in the night hours from 6 p.m. to 6 a.m. as against only 55·8 from 6 a.m. to 6 p.m., taking all the varieties together. The feeding activity and consequently the excretion were least during the hotter hours from 12 noon to 4 p.m. and maximum between 8 p.m. and 10 p.m. (Fig. 2). However, the differences between varieties in this regard were still maintained. The interaction between varieties and periods within day and night was not significant.

In all the above honeydew experiments it was observed that the honeydew droplets excreted by the leafhoppers that fed on susceptible and tolerant varieties were comparatively big, dark green, and opaque, while those on resistant varieties were much smaller, pale green to colourless, and translucent to transparent.

Discussion

It is interesting to note that under field as well as under insectary conditions, the jassid prefers the susceptible and tolerant varieties for feeding and oviposition (Tables 1 and 2). The efficiency with which the preferred host-varieties are discovered by the leafhoppers arouses interest and curiosity. The plausible explanation for their preference lies among other factors in the nutritional superiority of the susceptible and tolerant varieties over the resistant ones as surmised by Lipke & Fraenkel (1956) for phytophagous insects in general. In other words, the nutritional requirements of the jassid may have a direct bearing on host selection. In fact Painter (1958) has pointed out that not much emphasis has been placed on the use of resistant varieties, particularly resistant and susceptible isogenic pairs, as tools in the study of insect nutrition. The role played by the chemical senses of the insect in the matter of host selection may also be of much significance in this connection (Dethier 1953, 1954).

The susceptible variety Dominica and the tolerant variety C3. Pakistan contain higher quantities of total nitrogen, free amino acids, and peptides than the resistant R.C. 1098 Baker variety (Jayaraj 1967b). The resistant varieties were not preferred by the insect owing to their nutritional inferiority. These varieties had higher concentrations of total carbohydrates, sucrose and glucose than the susceptible and tolerant varieties, and in addition had fructose (Jayaraj 1967b). As the leafhoppers have been observed to avoid higher concentrations of sugars, particularly sucrose (Nuorteva 1952), the increased quantity of sugars present in resistant varieties may be supposed to repel the jassids.

As reported by Kennedy (1953) in the case of *Aphis fabae* Scop., the leafhopper *Empoasca flavescens* also seems to be capable of discriminating between different castor varieties and the leaves of different ages within the variety. The jassids are undoubtedly better adapted and in a better

position to do so than the aphids because of their more active habits. The middle and bottom leaves are generally preferred to the top leaves. Aphids, however, prefer tender leaves (Kessler *et al.* 1958 ; Kennedy 1958).

Maxwell & Painter (1959) reported the possibility of using the rate of honeydew deposition to measure the degree of resistance of host plants, the rate of ingestion of plant material, and to serve as a crude measure of the metabolic activity of the insect. The frequency of honeydew excretion was significantly higher in *E. flavescens* fed on the preferred hosts than when fed on nonpreferred resistant varieties (Fig. 1). Auclair (1958, 1959) observed that the honeydew droplet volume, the frequency, and rate of excretion in *Acyrthosiphon pisum* (Harr.) were generally proportional to the susceptibility of the pea variety. Maxwell & Painter (1959) also found increased frequency of honeydew excretion in *Toxoptera graminum* (Rond.) and *Therioaphis maculata* (Buck) fed on various alfalfa clones, and wheat and barley varieties varying in susceptibility to aphid attack.

The nymphs of *E. flavescens* excreted more honeydew than adults, and generally the female caused more damage than the male (Fig. 1). It has also been found that when the nymph/adult ratio is high, percentage hopperburn is high (Jayaraj 1967c), a phenomenon, in part, due to the voracious nature of the nymphs and their ability to drain more plant sap. The frequency of excretion by the adults of the aphid *Tuberolachnus salignus* (Gmelin) was much less than that of the nymphs (Mittler 1958) whereas in the aphid *Acyrthosiphon pisum* (Harr.) it was higher in the adults (Auclair 1958).

The higher deposition of honeydew in the night time recorded in the present studies (Fig. 2) may be because of the increased feeding activity of the leafhopper which prefers lower temperatures (Jayaraj 1964). The fact that red light retards the feeding and excretory activities of the leafhopper (Table 3) suggests an explanation for the less preference of the red-leaved variety R.C. 1092 Italy which is, however, a nontolerant variety classified under the susceptible category (Jayaraj 1967a).

Summary

In the mechanisms of resistance in castor (*Ricinus communis* L.) to the leafhopper, *Empoasca flavescens* (F.), the nonpreference component was found to play an important role. Evidence has been presented to show that for feeding and oviposition the insect preferred Dominica (susceptible) and C3. Pakistan (tolerant) varieties to the resistant R.C. 1098 Baker and R.C. 1096 Coonoor varieties. The preference among the 20 varieties was for the susceptible and tolerant types and for the middle and bottom leaves rather than the top leaves within the plant.

The nymphs and adults fed on susceptible and tolerant hosts excreted more honeydew than those fed on resistant plants. The excretion of honeydew was found to be more frequent in the case of nymphs as compared with adults. Normal feeding activity and excretion were observed on exposure to green, blue, and white lights, while yellow and red reduced the excretion. Excretion was significantly more during night than in the day, and was much retarded during the hotter hours on all the varieties.

The plausible mechanism of the preference or nonpreference is explained from the nutritional point of view.

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