RELATIONSHIP OF MORPHOLOGICAL AND ANATOMICAL CHARACTERS TO APHID INFESTATIONS IN CRUCIFERS

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INTRODUCTION

Of the various insect pests that attack the Indian domesticated Brassicas, the aphid, Lipaphis erysimii Kalt, is the most serious as it renders the crop a total failure in years of severe infestation. While breeding for aphid resistance in Brassica, experiments were conducted to find out the behaviour of the aphid in relation to different cruciferous genera to understand the principles underlying host-pest relationship and to determine the effect of morphological and anatomical characters of plants in making them tolerant/resistant to aphid infestation. The results from such a study are reported in the present investigation.

MATERIAL AND METHODS

Thirteen species including five genera of the family Cruciferae, eight subspecies of Brassica campestris, six synthetic amphidiploids of Brassica, classifed previously as resistant, tolerant and susceptible to aphid attack on the basis of aphid infestation and fecundity, were studied for different anatomical characters. One inch long terminal portion of tertiary branches, at 50% flowering, were cut and fixed in carnoy's fluid and preserved in formalin aceto alcohol. Hand sections of the fixed material were cut and examined under the microscope. The thickness of the cuticle, epidermis, collenchymatous and parenchymatous cells of the cortex, endodermis and pericycle were measured by means of an occular micrometer and they were converted into microns with the help of a stage micrometer. Similar technique was applied to measure the length of the probosis of aphid. A total of 30 sections were examined for each of the species, subspecies and amphidiploids. The depth of vascular bundles was measured in terms of the distance of phloem from the outer surface of the cuticle. This included the thickness of the cuticle, cortex, endodermis and pericycle. For finding out the number of vascular bundles, their total number irrespective of their stage of development were counted.

RESULTS

To find out the anatomical basis of variable reaction to aphid attack, anatomical survey of a number of species and subspecies of Brassica, *Crambe abyssinica*, *Raphanus sativus*, *Eruca sativa* and *Camelina sativa* and a few synthetic amphidiploids was made. They were divided into three groups-resistant, tolerant and susceptible to aphids- and were studied for the cuticle, epidermis, collenchyma and parenchyma cells of the cortex, endodermis, pericycle and the vascular bundles (Table-1).

Distinctive morphological features of different groups :

Resistant group : In *B. carinata* and *B. integrifolia* the stem was compact and hard. The cells in the cortical region had less intercellular space and were thick with high deposition. The vascular bundles were large, more or less equal in size, compact bicolateral and had large number of sclerenchymatous cells.

In *Eruca sativa* the stem was fibrous with more intercellular space in the cortical region. The vascular bundles were mostly small but deep seated.

The stem in *B. alba* and *B. hirta* was hard and compact with compact cortical cells with less intercellular space. There was high deposition in the first four collenchymatous cell-layers. The vascular bundles were situated deep down (Fig. 1a).

In *Crambe abyssinica* the cells on the ridges were small and thick with several layers. The vascular bundles were deep down particularly at the ridges.

Tolerant group : In *B. japonica* the stem was hard, vascular bundles bicolateral, compact, closely situated and having sclerenchymatous cells above the vascular bundles.

In *B. oleracea* the number of cell-layers in the cortical region was more with no intercellular space. The cortical cells were small, compact and thick due to heavy lignification. The vascular bundles were small in size but more in number.

The stem in *B. nigra* and *B. juncea* was hard with high deposition in the cortical layers. The vascular bundles were situated at medium depth, large in size, compact and had more sclerenchymatous cells (Fig. 1b).

Susceptible group : *B. campestris* subspecies var. *toria*, *B. campestris* subsp. *pekinensis*, *B. campestris* subsp. *chinensis* and *Camelina sativa* had very soft stem and shallow vascular bundles. In cortical region the cells were sparsely situated with more intercellular space (Fig. 1c and d). In these species the number of cortical cell-layers were comparatively less and had no deposition in the cells. The vascular bundles were small, loose and had less number of sclerenchymatous cells.

Correlations between anatomical characters and aphid fecundity :

Positive correlation (Table-2) of aphid fecundity was obtained with number of vascular bundles (0.24) and thickness of the cuticle (0.18) whereas the correlations were negative with the width of epidermis (-0.31), number of collenchyma cell layers (-0.07), width of collenchyma (-0.21), width of parenchyma (-0.32) width of endodermis (-0.10), number of pericycle cell layers (-0.32) width of pericycle (-0.37) and depth of vascular bundles (-0.57).

DISCUSSION

The insect-host relationship constitutes interactions between two diverse organisms and yet there is a close association between the two ; the former feeds and develops on the latter. The morphological and anatomical characters of plants play an important role in determining the nature of their association. The sap of the plants constitutes the food of aphids which draw their nutrition from the phloem cells through their stylets put forth intercellularly and intracellularly, more often through the former (Miles, 1958). In penetrating the plant tissues the stylets of the aphids have to pass through several layers of plant cells such as epidermis, cortex, pericycle and endodermis. The stylets of aphids feeding on resistant species such as *B. carinata, B. alba* and *Eruca sativa* seem to encounter difficulties in reaching the phloem cells on account of hard and a fibrous stem and thick and densely packed cortical cells without much air space in these plant species. Consequently they are either rejected or not preferred by the aphids. Therefore, hardness or toughness and thickness of different tissue layers of a plant species play a vital role in imparting aphid-resistance.

The most important anatomical feature contributing to insect-resistance was the depth at which the vascular bundles were situated. In the resistant group the vascular bundles were situated 196.60 u deep whereas in the tolerant and susceptible ones they were 142.00 and 115.77 u deep respectively. For feeding on plants with deep vascular bundles the aphid should have longer stylets as they have to traverse a greater distance to reach the phloem. Aphids with shorter stylets under these circumstances would be deprived of their food and consequently would die due to starvation. Their rate of fecundity also would be very low on such plant species with deep seated vascular bundles. Similar results were observed earlier by Berlinski (1965) in *Vicia faba* and by Gibson (1972) in Potato.

The total surface feeding area of the phloem element being small in the resistant group of species, due to the presence of less number of vascular bundles, the chances of the aphids feeding phloem cells appeared to be rather small as compared to the tolerant and susceptible groups where larger numbers of vascular bundles are present, which enables the aphids to search them out easily. Therefore, the possibilities of feeding large number of aphids on resistant species seem to be rather limited perhaps on account of this reason low aphid infestation and fecundity was observed on them.

When anatomical characters and population of aphids were considered together it was observed that there is a negative association between most of the anatomical characters and fecundity of aphids. The plant species with thicker and deeper vascular bundles harboured lower population of aphids. This further suggested that the depth of the vascular bundles play an important role in determining the aphid-resistance.

REFERENCES

Berlinski, K. (1965). Studies on food intake and the effects of food plants on the veet aphid, A. fabae (Russian). Polskii. Pismo. ent. (B) (1-2): 163-168.

Gibson, R.W. (1972). The distribution of aphids on potato leaves in relation to vein size. Entomologia expt. appl. 15(2): 213-223.

Miles, P.W. (1958). The stylet movements of a plant sucking bug, Oncopeltus fascinatus (Dall) (Heteroptera, Lygaeidae). Proc. R. Ent. Soc. Lond. (A) 33: 15-20.

Table 2 — Correlation coefficient values between the fecundity of aphids and anatomical characters of tertiary racemes of different crucifers.

Characters	1	2	3	4	5	6	7	8	9	10
Fecundity of aphids	0.18	−0.31	−0.07	−0.21	−0.32	−0.10	−0.32	−0.37	−0.57	−0.24

1. Thickness of cuticle
2. Thickness of epidermis
3. Number of collenchymatous layer
4. Thickness of collenchyma
5. Thickness of parenchyma
6. Thickness of endodermis
7. Number of pericyclic layer
8. Thickness of pericycle
9. Depth of vascular bundles
10. Number of vascular bundles.

Table-1 – Anatomical characters of terminal tertiary racems of cruciferous species and varieties

SPECIES/VARIETIES	Thickness (n)		Cortex				Thickness of Endodermis (μ)	Pericycle		Vascular Bundle	
	Cuticle	Epidermis	Callenchyma		Parenchyma			No. of layers	Thickness (μ)	Number	Depth (μ)
			No. of layers	Thickness (μ)	No. of layers	Thickness (μ)					
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
Resistant group											
B. integrifolis	7.70	21.80	5.0	77.77	4.6	66.22	21.56	7.2	87.01	16.0	254.10
B. carinata	5.77	11.35	6.1	100.12	3.0	70.38	10.75	2.6	39.95	16.0	173.24
B. alba	4.23	16.94	7.4	102.41	–	–	10.39	–	–	42.0	161.64
B. hirta	4.23	16.55	5.8	117.81	–	–	17.71	–	–	32.0	123.20
Eruca sativa	8.85	20.02	3.4	60.06	6.8	174.02	19.25	–	–	32.0	264.11
Crambe abyssinica	3.85	17.71	5.2	49.28	1.4	14.63	12.32	2.4	49.28	14.0	203.30
Mean	5.77	17.39	5.5	84.59	3.9	81.31	15.33	4.1	58.71	25.0	196.60
Tolerant group											
B. japonica	7.30	23.87	4.2	61.60	1.6	15.00	15.40	3.2	48.51	20.0	155.54
B. nigra	4.23	8.47	8.4	86.24	–	–	8.31	–	–	34.0	93.17
B. amarifolia	7.31	18.86	4.4	79.31	3.8	50.50	12.32	–	–	26.0	145.53
B. tournafortii	7.31	11.93	4.2	69.30	2.2	22.71	11.93	–	–	22.0	144.76
B. napus	8.08	15.76	5.2	78.54	–	–	16.55	–	–	22.0	131.67
B. olaraeca	10.05	13.36	9.4	154.77	–	–	18.48	–	–	56.0	198.41
Raphanus sativus	7.70	13.09	3.0	52.81	2.0	27.72	13.09	–	–	54.0	125.51
B. rapa	7.31	13.86	3.0	47.74	1.8	28.49	11.93	–	–	48.0	100.87
B. juncea	6.93	12.32	3.2	54.67	2.8	40.81	11.93	–	–	26.0	152.46
B. campestris var. yellow sarson	8.47	12.32	7.8	160.15	–	–	18.86	4.4	69.30	46.0	236.39
(B. chinensis x B. nigra)*	5.00	14.24	5.4	80.55	2.0	20.03	15.78	–	–	32.0	147.07
(B. pekinensis x B. nigra)*	7.70	9.24	5.6	74.69	3.0	28.49	15.40	–	–	50.0	117.81
(B. parinosa x B. nigra)*	6.50	11.93	6.0	63.14	–	–	8.47	–	–	38.0	90.86
(B. japonica x B. nigra)*	6.16	17.32	7.4	107.03	1.0	18.09	8.47	–	–	32.0	121.70
(B. chinonsis x B. oloracea)*	6.16	10.78	7.8	94.71	1.6	18.48	16.17	–	–	42.0	148.61
(B. campestris x B. oloracea)*	5.00	11.93	11.4	151.69	–	–	12.70	–	–	58.0	164.78
Mean	6.95	13.70	6.0	88.56	2.2	27.03	13.55	3.8	58.90	38.0	142.00
Susceptible group											
B. chinensis	7.70	16.01	3.8	54.67	–	–	8.54	–	–	16.0	98.56
B. nariposa	4.62	15.78	4.8	70.84	2.0	23.87	23.49	4.6	44.66	36.0	111.71
B. pekinensis	6.54	12.32	7.4	109.34	2.2	26.18	19.25	–	–	22.0	140.14
B. campestris var. toria	5.39	10.39	5.4	63.14	2.4	30.03	11.55	–	–	28.0	113.19
- do - var. brown garson (zero erucic)	8.47	7.70	6.2	73.15	–	–	8.55	–	–	32.0	88.55
Camelina sativa	7.70	8.08	3.6	55.44	1.2	14.63	16.94	–	–	36.0	142.45
Mean	6.74	11.71	5.2	71.10	1.9	23.68	14.72	4.6	44.66	28.0	115.77
Range	3.85–10.05	7.70–23.87	3.0–11.4	47.74–160.15	1.0-6.8	14.63–174.02	8.31–23.49	2.4–7.2	26.95–87.01	14.0–58.0	88.55–264.11
S.E.M.	0.33	0.68	0.34	5.10	0.33	9.14	0.76	0.64	6.36	1.99	8.28
C.D.	0.68	1.39	0.69	10.45	0.68	18.75	1.56	1.29	13.04	4.08	16.97

(–) = Nil   ** Synthesized amphidiploid.*

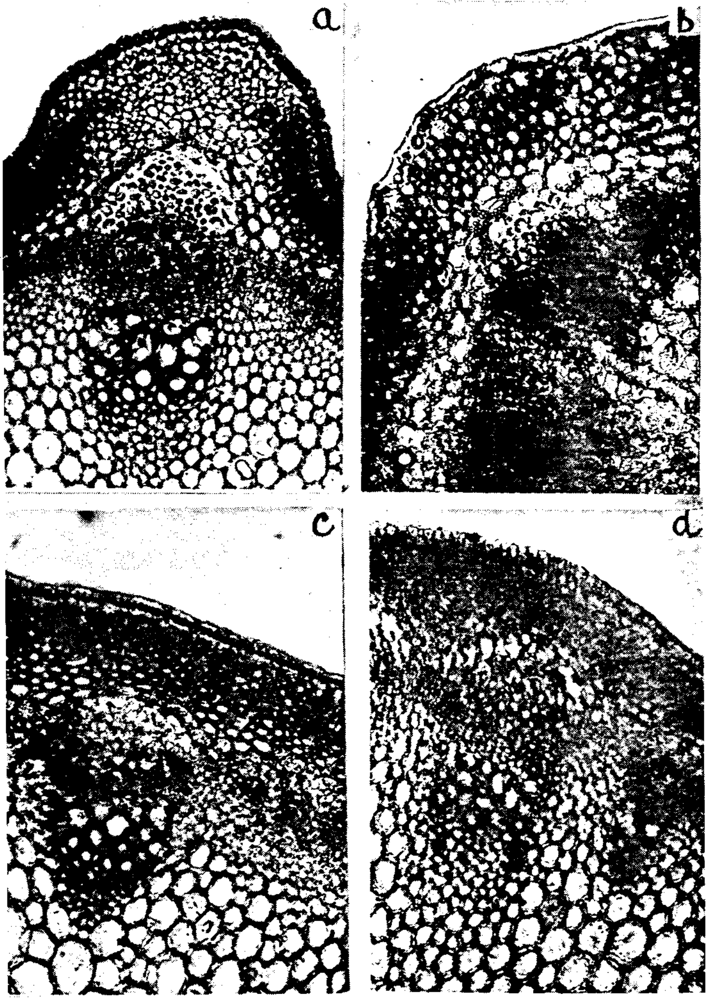

Figure 1. Transverse section of aphid resistant, tolerant and susceptible groups of Crucifers ;
a) Resistant (B. alba) note the deep seated vascular bundles and thick cortical cells, (b) tolerant (B. juncea) vascular bundles situated at medium depth and (c and d) susceptible (B. pekinensis, and B. campestris var. toria respectively) with shallow vascular bundles.