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Colonization and control of *Aphis craccivora* Koch (Homoptera: Aphididae) by coccinellid predators in some resistant and susceptible cowpea varieties in Nigeria

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Abundance of coccinellid predators in some varieties of cowpea, *Vigna unguiculata* (L.) Walp., of demonstrated resistance or susceptibility to the cowpea aphid, *Aphis craccivora* Koch, was observed in the field in 1989 and 1990 in Akure, Nigeria, following artificial aphid infestation. Highest aphid densities were developed in the susceptible varieties. Larvae of coccinellid predators were also more abundant in the susceptible than in the resistant varieties in both years. Predator larvae were generally more abundant on IT84S-2246-4, among the resistant varieties. Predator control of the cowpea aphid on caged susceptible and resistant cowpeas was also determined in a screenhouse. The cage evaluations indicated that the aphid resistance in IT84S-2246-4 can complement the activity of *Cheilomenes lunata* (F.) in reducing the population densities of *A. craccivora* and damage to infested plants.

Keywords: *Aphis craccivora*; coccinellid predators; aphid-resistant cowpea

The black cowpea aphid, *Aphis craccivora* Koch, is considered one of the most important pests of cowpeas, *Vigna unguiculata* (L.) Walpers, and related grain legumes in Africa, Asia and Latin America (Singh and van Emden, 1979; Jackai and Daoust, 1986). *A. craccivora* primarily infests cowpea seedlings causing stunting and frequently death. The aphid may infest cowpea in the post-flowering period, causing reduction in seed yield (Ofuya, 1989a). Considerable research efforts have been made to identify/develop resistant varieties for simple, economic and hazard-free control of the cowpea aphid (Singh, 1977; Jackai and Singh, 1988; Ofuya, 1988a, b; Singh *et al.*, 1990). The observation that strains of *A. craccivora* exist that appear to be unaffected by the resistance in the identified highly resistant cowpea varieties (van Emden, 1991) suggests the need for integrated control of the pest. In many cowpea-growing areas of Africa, low to moderate levels of varietal resistance may be sufficient because natural enemies, especially coccinellid predators, exercise some control of the cowpea aphid (Saharia, 1980; Ofuya, 1991). In this study, the possibility for combining host-plant resistance with the action of coccinellid predators in the control of *A. craccivora* on cowpeas was considered. The abundance of predatory coccinellid larvae in 12 varieties of cowpea (having various levels of resistance and susceptibility to *A. craccivora*) was monitored in the field in 1989 and 1990 in Nigeria, following artificial aphid infestation. Predator control of the aphid on caged resistant and susceptible cowpeas was also investigated.

Materials and methods

Cowpea varieties, aphid and predator culture

The cowpea varieties used were TVu 36, TVu 408, TVu 801, TVu 2896, TVu 3000, TVu 9914, TVu 9930, TVu 9944 and IT84S-2246-4, which have been reported to show seedling resistance, and Ife Brown, Vita 7 and IT84S-2231-15, which show high susceptibility at the seedling phase to *A. craccivora* (Singh, 1977; Jackai and Singh, 1988; Ofuya, 1988a, b). Their seeds were obtained from the Grain of Legume Improvement Programme of the International Institute of Tropical Agriculture, Ibadan, Nigeria. *A. craccivora* colonies were derived from field-collected individuals established and maintained as described by Ofuya (1989a). A colony of *Cheilomenes lunata* (Fabricius), which is perhaps the most prevalent predator of *A. craccivora*, was also maintained in the laboratory. Field-collected larvae and pupae were reared in glass Petri dishes (9.0 cm diameter), containing aphid-infested Ife Brown cowpea leaflets on moistened filter paper. Emerging adults were fed in Kilner jars containing aphid-infested cowpea shoots, and eggs laid by females were incubated in Petri dishes. Predator stages were fed daily with excess of aphids. All aphid transfers in this study were made with a damp camel-hair brush.

Resistance studies

These were conducted to ascertain the resistance/susceptibility of the selected varieties of cowpea to *A.*

craccivora. All 12 varieties were planted in pasteurized soil in individual plastic cups (0.79 l) and maintained at one seedling per cup, in the screenhouse. One seedling of each variety was separately infested with a prereproductive adult aptera of *A. craccivora* in a screened cage of muslin linen (60 × 60 × 90 cm), and the number of offspring it produced in 6 days was recorded. The 6-day fecundity of 20 prereproductive adult apterae was determined for each cowpea variety. Numbers of progeny reaching adulthood and producing offspring were also noted.

Field trials

The 12 cowpea varieties were planted in the main growing season (September–December) of 1989 and 1990 in Akure, southern Nigeria, in the vicinity of maize and okra fields infested by different aphid species that share common coccinellid predators with *A. craccivora* (Ofuya, 1991). Maize is commonly infested by *Rhopalosiphum maidis* (Fitch) and okra by *Aphis gossypii* Glover. Three replicated plots of each cowpea variety were planted in a randomized design. Each replicate consisted of three rows 1.0 m apart and each row consisted of 50 seedlings spaced 90 cm apart. Apart from routine manual weeding, no other cultural operations were carried out. All replicates were artificially infestated with *A. craccivora* (two prereproductive adult apterae per plant for 20 tagged plants randomly selected in each replicate) at 2 weeks after emergence. Thereafter, aphids and predators were counted on the tagged infested plants weekly for 6 weeks. Natural infestation of experimental plants by the aphid was not monitored. Only adult aphids (apterae) were counted, for convenience; adult apterae numbers in this species are positively correlated to local aphid population on a plant (T. I. Ofuya, unpublished data). In addition, only predator larvae were counted; in previous studies (Ofuya, 1991) predator larvae have been observed to be significantly correlated to aphid numbers.

Predator control of aphid on caged varieties

In these tests, the cowpea varieties IT84S-2246-4 (resistant) and Ife Brown (susceptible) were used. Three potted plants of each variety were placed in individual screened cages. Each seedling in the cages was infested with three prereproductive adult apterae of *A. craccivora* when the first trifoliate leaf was fully expanded. After 1 week, the aphids in each infested cage were counted. Immediately thereafter, each cage received a week-old adult pair of *C. lunata*. The predators were preconditioned before testing to standardize their levels of hunger by starving them for 24 h. For each variety, an infested control without predators and an uninfested control were set up at the same time. Aphids were counted at about midday each day, in all cages. The predators were usually not feeding at this time. All the plants in all cages were watered every other day, and seed yield was recorded at harvest. Each treatment, including the controls, was replicated four times.

Data analysis

All data were subjected to analysis of variance. Correlation analyses were further carried out between number of coccinellid larvae and aphid numbers at the different times in each planting. In the cage tests, paired *t* tests were used to compare percentage aphid mortality in the resistant and susceptible cowpeas.

Results

Resistance studies

Six-day fecundity of adult apterae of *A. craccivora* was lowest in TVu 3000, TVu 801 and TVu 401 seedlings, and highest on seedlings of Vita 7 and Ife Brown (*Table 1*). The percentage of progeny reaching adulthood and producing offspring was also lowest in TVu 3000 and TVu 801 followed by TVu 408 and TVu 36; it was highest in Ife Brown, Vita 7 and IT84S-2231-15.

Table 1. Fecundity and survival of *A. craccivora* on seedlings of selected cowpea varieties

Cowpea variety	No. of nymphs produced on seedling in 6 days (mean ± s.e.)	Percentage progeny survival (mean ± s.e.)
TVu 3000	3.2 ± 0.79	11.3 ± 1.83
TVu 801	5.6 ± 1.02	14.2 ± 2.23
TVu 408	6.8 ± 0.89	18.5 ± 3.48
TVu 36	8.2 ± 1.22	20.4 ± 3.04
TVu 9930	17.6 ± 3.21	38.2 ± 3.28
TVu 9944	17.8 ± 3.94	26.4 ± 2.77
TVu 9914	18.1 ± 4.23	34.6 ± 4.06
IT84S-2246-4	18.5 ± 2.88	32.8 ± 3.42
TVu 2896	19.4 ± 3.56	40.5 ± 4.84
IT84S-2231-15	44.3 ± 2.66	94.6 ± 2.86
Vita 7	46.1 ± 4.35	95.2 ± 3.61
Ife Brown	48.2 ± 5.24	96.4 ± 2.92
s.e.d. (d.f. = 11, 24)	2.34	3.45

Table 2. Numbers[a] of adult aphids (apterae) and predacious coccinellid (larvae) 2 weeks after artificial *A. craccivora* infestation of various cowpeas in the field in 1989 and 1990

	1989 planting		1990 planting	
Varieties	Aphids	Coccinellid larvae	Aphids	Coccinellid larvae
TVu 36	1.0	0.0	1.4	0.0
TVu 408	0.0	0.0	1.4	0.0
TVu 801	0.0	0.0	1.1	0.0
TVu 2896	5.3	1.1	6.3	1.3
TVu 3000	0.0	0.0	0.4	0.0
TVu 9914	4.7	0.8	5.1	1.1
TVu 9930	5.7	1.2	4.9	0.8
TVu 9944	4.4	1.0	5.3	0.9
IT84S-2246-4	4.6	1.8	5.7	2.8
Ife Brown	12.0	2.1	14.2	3.7
Vita 7	10.3	1.8	17.6	3.7
IT84S-2231-15	11.6	1.4	13.1	3.3
s.e.d. (d.f. = 11, 24)	1.94	0.41	1.87	0.49

[a]Values are mean numbers per plant

Table 3. Numbers[a] of adult aphids (apterae) and predacious coccinellid (larvae) 4 weeks after artificial *A. craccivora* infestation of various cowpeas in the field in 1989 and 1990

Varieties	1989 planting		1990 planting	
	Aphids	Coccinellid larvae	Aphids	Coccinellid larvae
TVu 36	0.0	0.0	0.0	0.0
TVu 408	0.0	0.0	0.0	0.0
TVu 801	0.0	0.0	0.0	0.0
TVu 2896	1.8	0.4	2.4	0.8
TVu 3000	0.0	0.0	0.0	0.0
TVu 9914	0.0	0.4	1.2	0.8
TVu 9930	0.0	0.0	0.4	0.0
TVu 9944	0.0	0.8	0.4	0.0
IT84S-2246-4	0.0	1.4	0.8	1.8
Ife Brown	26.2	8.7	18.4	6.6
Vita 7	31.3	10.3	12.2	5.3
IT84S-2231-15	28.4	8.0	14.1	5.8
s.e.d. (d.f. = 11, 24)	2.36	0.86	1.27	0.47

[a]As in *Table 2*

Field studies

Observations presented in *Tables 2* and *3* show that after artificial infestation with *A. craccivora*, the various cowpeas were invaded by coccinellid predators during both years. After the fifth week following artificial aphid infestation, only the susceptible cowpea varieties had aphids or predators; the data, therefore, are not presented. The coccinellids belonged mainly to the genera *Cheilomenes* and *Scymnus*, which have been previously identified (Booker, 1964; Don Pedro, 1980; Akingbohungbe, unpublished data). Syrphid larvae were also observed, but coccinellids are usually more prevalent seasonally (Ofuya, 1989b). *C. lunata* was the most abundant of the coccinellids. Aphid densities were significantly ($p < 0.05$) higher in the susceptible than in the resistant cowpea varieties. Similarly, greater numbers of predator larvae were found on the susceptible than on the resistant varieties. There was a significant ($p < 0.0001$) positive correlation between aphid numbers with number of coccinellid larvae (r = 0.89 and 0.99 for weeks 2 and 4 in the 1989 planting, respectively, and 0.94 and 0.98 for weeks 2 and 4 in the 1990 planting, respectively). The cowpea variety IT84S–2246-4, with low aphid resistance, was colonized by more coccinellids than the other resistant varieties.

Predator control of aphid on caged varieties

Table 4 shows that an aphid population established on three potted plants in 1 week by nine adult apterae of *A. craccivora* was completely controlled by an adult pair of *C. lunata* in 2 days on the resistant cowpea IT84S-2246-4, but in 5 days on the susceptible variety, Ife Brown. There was significant higher aphid mortality on the resistant cowpea/predator combination than on the susceptible cowpea/predator combination from day 1 to 2 following predator introduction ($t = 29.24$, d.f. = 3; $p < 0.05$), but not from day 0 to 1 ($t = 2.76$, d.f. = 3; $p > 0.05$). The inherent aphid resistance in IT84S-2246-4 could not completely control the aphid population in 5 days. Seed yield in aphid-infested IT84S-2246-4 plants with predator and that obtained in control plants (without aphid or predator) were similar, but significantly ($p < 0.05$) higher than seed yield in aphid-infested plants without predator (*Table 5*). Seed yield in Ife Brown plants without aphid or predator was significantly ($p < 0.05$) higher than in aphid-infested plants with predator, which was in turn also significantly higher than in aphid-infested plants without predator.

Discussion

The results of the resistance studies largely corroborate the reported resistance and susceptibility levels of the selected cowpea varieties to *A. craccivora* (Singh, 1977;

Table 5. Seed yield (g) in plants of a susceptible and resistant cowpea variety infested with *A. craccivora* and subjected to predation by *C. lunata*

Treatment	Mean seed yield (g per plant)	
	IT84S-2246-4 (resistant)	Ife Brown (susceptible)
Aphid-infested plants with predator	1.9	1.3
Aphid-infested plants without predator	1.5	0.0
Plants without aphid or predator	2.1	1.9
s.e.d. (d.f. = 2, 9)	0.17	0.23

Table 4. Predator control of *A. craccivora* on a susceptible and resistant cowpea separately infested with nine adult apterae of aphid 1 week before predator introduction

Treatment		Mean no. of aphids following predator introduction[a]					
Cowpea variety	Predator presence (+) or absence (−)	Day 0	Day 1	Day 2	Day 3	Day 4	Day 5
IT84S-2246-4[b]	+	12.4	7.9 (36.3)[c]	0 (100)			
IT84S-2246-4	−	12.7	11.5 (9.4)	10.9 (5.2)	9.4	7.5	8.1
Ife Brown[d]	+	25.3	22.4 (11.5)	17.9 (20.1)	13.5	7.4	0
Ife Brown	−	25.1	29.3	33.4	35.1	37.3	38.4

[a]Means are square-root transformed values; [b]resistant variety; [c]values in parentheses are percentage aphid mortality; [d]susceptible variety

Jackai and Singh, 1988; Ofuya, 1988a, b; 1993). The general observation that coccinellid larvae were more abundant on varieties with higher aphid density supports the density-dependence hypothesis advanced by Hassell and Rogers (1972), which has also been reported by many other workers (Horn, 1981; Hassell, 1985; Ofuya, 1991). In the cowpea varieties that have high resistance, such as TVu 3000, TVu 801 and TVu 408, *A. craccivora* could not become established and therefore the natural enemies could not find an adequate host population to invade. Van Emden (1966) used a simple mathematical model to show that partial host-plant resistance interacting with natural enemies of pests could prevent pest outbreaks in certain situations. Only a relatively few empirical studies (Kartohardjono and Heinrichs, 1984; Maxwell, 1991) have been reported in this area. The studies on aphid control by *C. lunata* in the caged infested plants clearly showed that the low aphid resistance in the cowpea variety IT84S-2246-4 complemented the activity of the adult predators, in the more rapid and complete suppression of the established *A. craccivora* population and prevention of seed yield loss. Indeed, the significantly higher aphid mortality on the resistant cowpea with predator (100%) than on the susceptible with predator (20.1%) from day 1 to day 2, suggest a beneficial interaction between plant resistance and biocontrol. In the field, predator larvae were generally more abundant on IT84S-2246-4 than on the other varieties of low aphid resistance. This feature may have been especially useful if the partial resistance is conferred by tolerance that enables the pest species to build to populations that attract natural enemies and allow such enemies to increase to effective levels. However, aphids did not build up on the variety.

The various reasons that may account for beneficial interaction between partial host-plant resistance and biological control have been summarized by van Emden (1991). The IT84S-2246-4/*A. craccivora*/natural enemies system is the subject of a more detailed investigation. According to Bergman and Tingey (1979), the use of partial plant resistance and natural enemies should be of long-term benefit because pests would not adapt to such a system as rapidly as they would to a system in which a strong resistance factor was used as a unilateral approach to pest suppression.

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