Tolerance of different host-plants to the cassava mealybug *Phenacoccus manihoti* Matile-Ferrero (Homoptera: Pseudococcidae)

(*Keywords:* *Phenacoccus manihoti*, cassava, insect–plant relationship, antibiosis, tolerance, varietal resistance, Congo)

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Abstract. The tolerance of seven varieties of cassava (*Manihot esculenta* Crantz), Poinsettia (*Euphorbia pulcherrima* Wild.), Talinum (*Talinum triangulare* Jacq.) and Faux-caoutchouc (a hybrid of *M. esculenta* and *M. glaziovii* Mull. Arg.) to the cassava mealybug *Phenacoccus manihoti* Matt. Ferr., was measured in the laboratory, by quantifying morphological and physiological changes in the growth of plants infested with *P. manihoti*. A 2-month infestation by 100 mealybugs decreased the total leaf area and the leaf area ratio $\bar{F}$, but did not modify total dry weight, relative growth rate $\bar{R}$ or net assimilation rate $\bar{E}$ of plants studied. The decrease in leaf area was extremely variable and depended on plant species and variety. The effect of infestation on dry weight of different plant organs was not homogeneous, suggesting that translocation of nutrients made during photosynthesis was modified. In cassava the decrease in leaf area, without significant change in leaf dry weight, appeared to be due to physiological changes in plants similar to those induced by water stress. The degree of tolerance was not related to the plant species (cassava varieties Ganfo, Incoza and Zanaga were as tolerant as Talinum and Faux-caoutchouc).

1. Introduction

Tolerance is a component of plant resistance and relates to its capacity to withstand insect attacks which would otherwise affect the growth of susceptible plants (Horber, 1980). Unlike antixenosis and antibiosis, it does not exert a strong selective pressure on insect pest populations; thus it can be maintained in a population over a long period (Auclair, 1989; Jimenez *et al.*, 1988).

Cassava (*Manihot esculenta* Crantz; Euphorbiaceae) is a perennial shrub plant, relatively tolerant to diseases and pests because, unlike most other cultivated plants, it does not have critical phases during its development which can possibly affect the yield. However, yield losses are high if the lifespan of leaves and the rate of photosynthesis are decreased or if stems are damaged severely (Cock, 1979). A field experiment done in Nigeria has shown that the infestation of cassava by the mealybug *Phenacoccus manihoti* Matile Ferrero (Homoptera; Pseudococcidae) results in a yield loss ranging between 52% and 58% in 12-month-old plants. This loss might be due to a decrease in growth rate and leaf area; the latter might strongly influence the total production of dry matter and its redistribution to roots (Schulthess *et al.*, 1991).

These modifications in growth due to the infestation of *P. manihoti* are similar to those induced by other sucking insects such as Cicadellidae (Andrzejewska, 1967) and Aphididae (Dixon, 1971a,b; Barlow *et al.*, 1977; Barlow and Messmer, 1982; Hawkins *et al.*, 1985, 1986). Their quantification provides a useful tool to evaluate the degree of plant tolerance (Jimenez *et al.*, 1989; Scott *et al.*, 1991; Webster *et al.*, 1991).

When evaluating components of host-plant resistance to *P. manihoti*, different degrees of resistance in terms of antixenosis and antibiosis have been demonstrated (Le Rü *et al.*, 1991a). The aim of the present study is to determine the cassava tolerance to *P. manihoti* by quantifying morphological and physiological changes in their growth caused by pest infestation.

2. Materials and methods

The 10 host-plants used in this study were selected according to the results obtained in a previous experiment done to assess the antixenotic and antibiotic relationships between *P. manihoti* and its host-plants (Le Rü *et al.*, 1991a). The seven varieties of cassava (*M. esculenta*) have a varying degree of resistance in terms of antixenosis and antibiosis (high resistance: Incoza, Moudouma, and Zanaga; medium resistance: M'Pembe, 30 M7; low resistance: 3 M8, Ganfo).

We also measured the tolerance of Faux-caoutchouc (a hybrid of *M. esculenta* and *M. glaziovii* Mull. Arg.), Talinum (*Talinum triangulare* Jaq., Portulacacae) and Poinsettia (*Euphorbia pulcherrima* Wild., Euphorbiaceae); their biological characteristics are as follows:

1. Faux-caoutchouc hosts large populations of *P. manihoti* throughout the year, unlike cassava on which they are present for only 3–5 months (Iheagwam, 1981).
2. Talinum is a weedy plant found in cassava fields, and can sometimes host large populations of cassava mealybugs (Neuenschwander *et al.*, 1986).
3. Poinsettia is sometimes used in the laboratory as a substitute for cassava to mass-rear mealybugs (A. Panis and J. Boussienguet, personal communication), although it is never infested with this pest under natural conditions in Congo.

Plants were obtained from 30 cm cuttings planted vertically with two-thirds of their length in soil held in plastic pots (30 × 22 cm). Pots were left in the shade for 2 weeks to

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stimulate the rooting process. Thereafter they were placed in full light until the 9–10-leaf stage (about 70 cm in height) which took 9–10 weeks. Pots (30 of each host-plant) were then left for a further 2 months in a growth chamber under controlled conditions with an average temperature of 25°C (minima–maxima 21–32°C) and an average relative humidity of 70% (ranging between 60% and 80%); photoperiod was 12 hours L:D. Under these experimental conditions we obtained after a 4-month period, plants with approximately 20 leaves and about 90–100 cm in height. Under natural conditions in Congo, attacks by mealybugs occur at the beginning of the dry season on plants 3–8 months old derived from the propagation of cassava cuttings, mostly performed between November and April. Pots were watered twice a week during all the experiment.

The strain of *P. manihoti* (species reproducing by thelytocous parthenogenesis) used for the experiment in the laboratory was collected on the M'Pembe variety in the vegetable crop area of Brazzaville in October 1988. In order to limit the influence of parental trophic feeding mealybugs were reared for four generations (6 months) on each of the host-plants used in this experiment.

At time 0 (T_0), 15 plants per host-plant, of identical size, without symptoms of African cassava mosaic virus, were chosen amongst the 30 cuttings prepared initially. These were divided randomly into two groups: one group of five plants which was harvested 2 months later at time T_1. Each pair consisted of a control plant (non-infested) and a treated plant (infested with 100 neonate mealybug L1 larvae, less than a day old). These conditions of infestation (100 mealybugs per plant for 2 months) were representative of the maximum number usually observed 2 months after the beginning of gradation in Congo (Le Rü *et al.*, 1991b). The artificial infestation is done on the second and third leaves from the apex with young neonate larvae. They attach themselves to the plant within the first 48 hours, resulting in a homogeneous infestation of plants by *P. manihoti*. We then count and readjust their number to 100 (by removing or adding mealybugs of the same stage) during all experiments, in order to have an identical number on all infested plants. Finally, when mealybugs reach the L4 stage with ovisacs, we remove the ovisacs each week to prevent new larvae from hatching and to keep the total number constant.

The following parameters were determined at time T_0 and T_1 on control and experimental plants for each host-plant: the average number of leaves, the average number of internodes, the average stem length between the internodes, the mean leaf area, the dry weights of leaves, stems, cuttings and roots. Leaf areas were determined using the equation: $\log (LA) = -7{\cdot}47 + 2{\cdot}460 \log (MLL)$ (LA = leaf area in cm^2; MLL = median lobe length in cm) (Hammer, 1980). Dry weights were measured after drying the plant material in a 50°C oven for 4 days.

From these parameters we determined three indices $\bar{R}$, $\bar{E}$ and $\bar{F}$ which were used to characterize the physiological state of a plant. The relative growth rate $\bar{R}$ for a period of time can be expressed as:

$$\bar{R} = (\ln W_1 - \ln W_0) \,/\, T_1 - T_0$$

where W_0 and W_1 are the total dry weights at the beginning (T_0) and end (T_1) of the time period; $\bar{R}$ indicates the variation in plant weight per unit of time.

The rate of net assimilation $\bar{E}$ is:

$$\bar{E} = (W_1 - W_0)/(T_1 - T_0) \times ((\ln A_1 - \ln A_0)/(A_1 - A_0))$$

where A_0 and A_1 are the leaf areas at times T_0 and T_1 respectively; $\bar{E}$ is an approximate measure of the net photosynthetic rate (Causton and Venus, 1981). In a constant environment, $\bar{E}$ can be considered as an index of the plant's productive efficiency (Williams, 1946).

The leaf area ratio $\bar{F}$ is:

$$\bar{F} = (A_0 \,/\, W_0) + (A_1 \,/\, W_1) \,/\, 2$$

This is a morphological index of the plant, and assumes that leaves are the sole assimilatory organs (Causton and Venus, 1981).

Mean values were analysed statistically using a *t*-test at the 5% level.

3. Results and Discussion

Infestation of *P. manihoti* decreased the total leaf area of all host-plants studied; however, this decrease was significant only for the Faux-Caoutchouc and for varieties of cassava Moudouma, Ganfo Zanaga, 30 M7 and M'pembe. Infestation also reduced significantly the average number of leaves in the varieties of cassava 3 M8 and 30 M7, as well as the average number of internodes in the variety 3 M8 and Talinum, and the stem length between internodes in the variety Moudouma (Table 1). The general decrease in leaf area was found to depend on the plant itself. Compared to Schulthess *et al.*'s (1991) work on only one variety of cassava (TMS 30572), our study shows that although the infestation of *P. manihoti* is characterized by a decrease in leaf area, it can be variable depending on the variety, and ranges between 7% and 56%. When plant growth was analysed in detail—for instance by taking into account the average number of leaves, number and average length of internodes—we then found that the development of plants was affected only to a small extent by mealybug infestation (Table 1). When infestation modified plant growth significantly, it decreased either the lifespan of leaves (30 M7) or their rate of development (Talinum) or both (3 M8). Our results do not suggest a general pattern for the effect of mealybug infestation on the growth of cassava.

The total dry weight of the 10 host-plants studied was not significantly modified by infestation. However, a significant decrease in leaf dry weight was observed for the cassava varieties Incoza and 30 M7, and in the stem dry weight of the latter variety (Table 2). This result disagrees with previous results obtained for the cassava mealybug (Schulthess *et al.*, 1991) and, in general, for aphids (Hawkins *et al.*, 1985; Wellings *et al.*, 1989) which reported a reduction in dry weights of plants after infestation. This discrepancy cannot be attributed to the relatively short duration of the experiment. In natural conditions duration of gradation was about 2–3 months.

However, we did observe that the total dry weight of

Table 1. Mean ± SE leaf area, number of leaves, number of internodes and stem length between the internodes for control and infested (100 mealybugs during 2 months) plants, of seven cassava varieties (Incoza, Moudouma, Zanaga, 3 M8, M'Pembé, Ganfo, 30 M7), Faux-caoutchouc, Poinsettia and Talinum; t-values are presented followed by S (significantly different) or by NS (not significantly different)

Host-plant	State	Leaf area (cm^2)	Number of leaves	Number of internodes	Stem length between internodes (cm)
Poinsettia	Control	45·65 ± 2·40	9·00 ± 2·73	36·60 ± 9·94	1·75 ± 0·57
	Infested	43·12 ± 22·86	13·20 ± 8·28	27·00 ± 13·49	2·04 ± 0·73
		0·21(NS)	1·07(NS)	1·28(NS)	0·69(NS)
Talinum	Control	9·56 ± 4·037	42·00 ± 12·28	49·60 ± 11·26	1·32 ± 0·40
	Infested	8·53 ± 1·84	39·80 ± 19·51	27·00 ± 13·49	1·33 ± 0·34
		0·51(NS)	0·21(NS)	2·87(S)	0·05(NS)
Dicotoma	Control	100·27 ± 7·30	7·00 ± 1·87	23·20 ± 2·86	5·50 ± 0·80
	Infested	54·106 ± 27·80	9·20 ± 1·48	23·60 ± 2·40	4·12 ± 1·18
		3·59(S)	2·06(NS)	0·23(NS)	2·15(NS)
Moudouma	Control	63·94 ± 6·81	15·40 ± 1·81	40·00 ± 4·24	2·89 ± 0·28
	Infested	30·91 ± 9·18	15·00 ± 3·08	41·60 ± 3·78	2·35 ± 0·15
		6·81(S)	0·25(NS)	0·63(NS)	3·66(S)
3 M8	Control	35·58 ± 10·71	11·60 ± 2·40	41·00 ± 5·09	1·89 ± 0·28
	Infested	30·04 ± 13·29	5·20 ± 5·16	32·00 ± 6·74	1·88 ± 0·29
		0·72(NS)	2·51(S)	2·38(S)	0·05(NS)
Ganfo	Control	22·73 ± 3·94	17·00 ± 3·31	49·20 ± 0·83	1·12 ± 0·04
	Infested	14·60 ± 5·06	13·00 ± 4·84	47·00 ± 4·52	1·11 ± 0·07
		2·83(S)	1·52(NS)	1·06(NS)	0·09(NS)
Incoza	Control	41·89 ± 7·83	9·60 ± 2·07	32·60 ± 3·28	2·24 ± 0·29
	Infested	38·62 ± 12·72	4·00 ± 1·00	32·00 ± 2·91	2·13 ± 0·28
		0·49(NS)	5·43(NS)	0·30(NS)	0·59(NS)
Zanaga	Control	51·04 ± 7·43	14·20 ± 2·16	47·20 ± 2·95	1·88 ± 0·20
	Infested	37·79 ± 9·71	13·80 ± 2·77	42·00 ± 2·34	1·71 ± 0·17
		2·42(S)	0·25(NS)	3·08(NS)	1·43(NS)
30 M7	Control	86·38 ± 10·83	20·00 ± 4·00	42·60 ± 6·87	2·76 ± 0·31
	Infested	39·96 ± 9·86	10·40 ± 4·72	33·00 ± 7·17	2·45 ± 0·39
		7·08(S)	3·46(S)	2·16(NS)	1·37(NS)
M'pembé	Control	67·65 ± 13·80	14·20 ± 2·16	38·80 ± 5·54	2·38 ± 0·15
	Infested	29·71 ± 11·38	13·60 ± 4·45	40·80 ± 2·38	2·58 ± 0·33
		4·47(S)	0·27(NS)	0·74(NS)	1·20(NS)

cassava variety 30 M7 was greatly decreased by infestation (although not to a significant level). This result suggests that the absence of a reduction in dry weight in all other host-plants studied is truly linked to their tolerance to *P. manihoti*. At the level of the plant organ, this reduction affected mainly leaves and stems (significant reduction). Overall, if all species and varieties are put together, the effect of mealybug infestation was not homogeneous on all organs of infested plants; damage was more severe on aerial parts (the dry weight of leaves of Poinsettia was multiplied by 3 and that of 30 M7 reduced by 64%) than on underground parts (the dry weight of roots of Poinsettia and Talinum were reduced by 50% and, within the cassava species, the highest reduction recorded was 36% in Incoza).

This observation suggests that mealybug infestation modifies the translocation of plant nutrients produced during photosynthesis. A similar observation has been made in cucumber and broadbean infested with phloem-feedings insects (Brinkmann *et al.*, 1990) and also on broadbean infested with *Aphis fabae* Scop. (Homoptera: Aphididae). However, this phenomenon is not general; Wu and Thrower (1981) reported a homogeneous effect on all organs of *Vigna sequipedalis* Fruw. infested with *Aphis craccivora* Koch.

In all instances except one (the 30 M7 variety was significantly stunted), the relative growth rate $\bar{R}$ was not altered significantly by mealybug infestation (Table 3). The net assimilation rate $\bar{E}$ was also unaffected but the ratio of leaf area $\bar{F}$ was modified significantly by mealybug infestation in the varieties of cassava Moudouma, 3 M8, 30 M7 and M'pembe. This result differs from those obtained with aphids (Mallot and Davy, 1978; Barlow and Messmer, 1982; Hawkins *et al.*, 1985, 1986; Prüter and Zebitz, 1991), where infestation is characterized by a reduction in $\bar{R}$ and $\bar{E}$, $\bar{F}$ remaining unchanged. The absence of change in $\bar{F}$, which is an approximation of the net rate of assimilation, would suggest that the productivity of plants remains unchanged. Nevertheless, the reduction in leaf area without significant modification in leaf dry weight may correspond

Table 2. Mean ± SE leaf, stem, root, cutting and total plant dry weights for control and infested (100 mealybugs during 2 months) plants, of seven cassava varieties (Incoza, Moudouma, Zanaga, 3 M8, M'Pembé, Ganfo, 30 M7), Faux-caoutchouc, Poinsettia and Talinum; t*-values are presented followed by S (significantly different) or by NS (not significantly different)*

		Dry weight (g)				
Host-plant	State	Leaf	Stem	Cutting	Root	Plant
Poinsettia	Control	0·33 ± 0·20	2·83 ± 0·38	6·67 ± 2·26	0·74 ± 0·41	10·57 ± 2·18
	Infested	0·97 ± 0·69	3·28 ± 1·78	6·63 ± 3·20	1·04 ± 0·69	12·95 ± 5·09
		1·99(NS)	0·55(NS)	0·02(NS)	0·82(NS)	0·96(NS)
Talinum	Control	0·68 ± 0·21	4·35 ± 1·98	1·12 ± 0·23	0·27 ± 0·11	6·42 ± 2·13
	Infested	0·59 ± 0·29	4·45 ± 0·99	1·61 ± 0·43	0·42 ± 0·09	7·072 ± 1·09
		0·55(NS)	0·09(NS)	2·23(NS)	2·07(NS)	0·60(NS)
Dicotoma	Control	3.58 ± 0.92	16·96 ± 5·44	10·33 ± 1·88	0·56 ± 0·20	31·44 ± 6·59
	Infested	3·79 ± 0·80	16·13 ± 4·73	10·33 ± 2·14	0·60 ± 0·08	30·86 ± 5·73
		0·38(NS)	0·25(NS)	0·002(NS)	0·34(NS)	0·14(NS)
Moudouma	Control	3·48 ± 0·73	8·15 ± 2·08	10·67 ± 7·84	0·90 ± 0·58	23·22 ± 9·98
	Infested	2·55 ± 1·15	8·27 ± 3·72	12·54 ± 5·10	0·64 ± 0·20	24·01 ± 8·19
		1·51(NS)	0·05(NS)	0·44(NS)	0·93(NS)	0·13(NS)
3 M8	Control	1·66 ± 0·69	5·44 ± 1·45	17·20 ± 1·03	1·11 ± 0·91	25·58 ± 1·19
	Infested	0·78 ± 0·70	4·08 ± 0·84	21·81 ± 8·94	0·68 ± 0·65	27·37 ± 9·67
		1·98(NS)	1·80(NS)	1·14(NS)	0·84(NS)	0·41(NS)
Ganfo	Control	2·30 ± 0·66	3·24 ± 0·63	8·84 ± 6·04	0·61 ± 0·31	15·55 ± 5·92
	Infested	1·54 ± 0·44	3·19 ± 0·58	7·38 ± 4·60	0·53 ± 0·16	12·85 ± 4·42
		2·12(NS)	0·12(NS)	(NS)	0·52(NS)	0·81(NS)
Incoza	Control	1·80 ± 0·33	6·43 ± 0·73	23·23 ± 14·90	1·76 ± 1·59	33·22 ± 15·60
	Infested	0·84 ± 0·30	7·29 ± 2·27	27·16 ± 10·68	1·12 ± 0·72	36·42 ± 10·00
		4·75(S)	0·80(NS)	0·48(NS)	0·81(NS)	0·38(NS)
Zanaga	Control	2·82 ± 0·49	4·77 ± 1·67	9·92 ± 2·42	0·78 ± 0·21	18·30 ± 4·26
	Infested	2·70 ± 0·88	3·96 ± 1·78	8·82 ± 1·82	0·95 ± 0·64	16·43 ± 4·22
		0·27(NS)	0·73(NS)	0·81(NS)	0·53(NS)	0·69(NS)
30 M7	Control	4·10 ± 0·52	8·08 ± 2·94	12·32 ± 7·86	0·47 ± 0·05	24·91 ± 9·58
	Infested	1·48 ± 0·54	2·95 ± 1·44	6·20 ± 2·89	0·44 ± 0·25	11·02 ± 4·65
		7·70(S)	3·49(S)	1·63(NS)	0·27(NS)	2·91(NS)
M'pembé	Control	3·09 ± 0·95	8·08 ± 2·94	10·30 ± 5·65	0·55 ± 0·20	19·42 ± 8·72
	Infested	2·37 ± 1·17	5·46 ± 1·86	11·00 ± 5·52	0·56 ± 0·15	19·41 ± 5·91
		1·06(NS)	1·67(NS)	0·19(NS)	0·12(NS)	0·004(NS)

to a physiological change in plants; it is characterized by an increase in the proportion of available assimilates, related to a decrease in the water content of leaves. The physiological changes in cassava induced by mealybug infestation, similar to those triggered by water stress (El-Sharkawy and Cock, 1987), suggest that the underlying mechanisms in response to stress may be identical in both cases.

With the exception of the cassava variety 30 M7 all varieties studied were tolerant to mealybug infestation. The degree of tolerance was not related to the plant species (cassava varieties Ganfo, Incoza and Zanaga were as tolerant as Talinum and Faux-caoutchouc) and the type of response to infestation, within the cassava species, depended on variety. Our results confirm the relative tolerance of cassava to pest attacks reported earlier by Cock (1979). He suggested that tolerance could be due to the absence of a critical growth phase in cassava, and also to its capacity to compensate losses caused by diseases and pests when favourable conditions return. However, tolerance appears to depend on variety. We observed different degrees of tolerance to the mealybug within the varieties of cassava. Thus, three cassava varieties—Ganfo, Incoza and Zanaga (only one of the three parameters studied was modified significantly by infestation)—were more tolerant than varieties 3 M8 and Moudouma (all three parameters modified by infestation), themselves more tolerant than variety 30 M7 (seven parameters altered by infestation).

The present work on the tolerance of various host-plants complements a recent study on antibiosis and antixenosis (Le Rü *et al.*, 1991a). The different components of resistance of host-plants of *P. manihoti* have been assessed: apart from Poinsettia and Talinum, which showed an antixenotic type of resistance to the mealybug (close to immunity), the other eight plants, which belong to the genus *Manihot*, developed a partial antibiotic type of resistance and tolerance. In varietal breeding programmes various degrees of resistance should be taken into account, as it should reduce pest damage to an acceptable, economical level and it appears more appropriate rather than selecting immune varieties (Auclair,

Table 3. Mean ± SE net relative growth rate (R̄), mean + SE unit leaf rate (Ē) and mean leaf area ratio (F̄) for control and infested (100 mealybugs during 2 months) plants, of seven cassava varieties (Incoza, Moudouma, Zanaga, 3 M8, M'Pembé, Ganfo, 30 M7), Faux-caoutchouc, Poinsettia and Talinum; t-values are presented followed by S (significantly different) or by NS (not significantly different)

Host-plant	State	$\bar{R}$ (g . g^{-1} . day^{-1})	$\bar{E}$ (mg . cm^{-2} . day^{-1})	$\bar{F}$ (cm^2 . mg^{-1})
Poinsettia	Control	0·022 ± 0·003	1·840 ± 0·080	0·114 ± 0·011
	Infested	0·024 ± 0·007	1·912 ± 0·091	0·137 ± 0·028
		0·69(NS)	1·03(NS)	1·69(NS)
Talinum	Control	0·039 ± 0·002	2·108 ± 0·096	0·137 ± 0·014
	Infested	0·037 ± 0·005	2·170 ± 0·094	0·126 ± 0·029
		0·87(NS)	1·03(NS)	0·75(NS)
Dicotoma	Control	0·036 ± 0·004	2·394 ± 0·358	0·050 ± 0·008
	Infested	0·035 ± 0·003	2·326 ± 0·174	0·042 ± 0·012
		0·19(NS)	0·38(NS)	1·34(NS)
Moudouma	Control	0·025 ± 0·006	1·886 ± 0·225	0·068 ± 0·014
	Infested	0·026 ± 0·005	1·834 ± 0·260	0·041 ± 0·007
		0·16(NS)	0·33(NS)	3·77(S)
3 M8	Control	0·023 ± 0·001	1·494 ± 0·106	0·030 ± 0·009
	Infested	0·023 ± 0·001	1·214 ± 0·591	0·017 ± 0·004
		0·06(NS)	1·04(NS)	3·00(S)
Ganfo	Control	0·031 ± 0·007	2·062 ± 0·204	0·070 ± 0·012
	Infested	0·028 ± 0·006	1·990 ± 0·213	0·063 ± 0·013
		0·79(NS)	0·55(NS)	0·94(NS)
Incoza	Control	0·024 ± 0·009	1·702 ± 0·533	0·029 ± 0·011
	Infested	0·027 ± 0·005	1·734 ± 0·587	0·018 ± 0·003
		0·61(NS)	0·09(NS)	2·20(NS)
Zanaga	Control	0·027 ± 0·004	1·932 ± 0·097	0·079 ± 0·009
	Infested	0·025 ± 0·004	1·870 ± 0·111	0·070 ± 0·009
		0·57(NS)	0·94(NS)	1·58(NS)
30 M7	Control	0·031 ± 0·007	2·042 ± 0·125	0·117 ± 0·029
	Infested	0·017 ± 0·008	1·682 ± 0·171	0·077 ± 0·012
		3·05(S)	3·80(S)	2·87(S)
M'pembé	Control	0·027 ± 0·008	1·952 ± 0·180	0·137 ± 0·014
	Infested	0·028 ± 0·007	1·952 ± 0·230	0·126 ± 0·029
		0·17(NS)	0·00(NS)	0·75(NS)

1989). Furthermore, in the context of a cassava crops, requiring very few treatments, the use of partially resistant cultivars represents an efficient and economical method of pest control. In future, all selection programmes for cassava varieties should aim to identify varieties with strong antibiotic components and with a relatively high tolerance, such as varieties Zanaga and Incoza. Other parameters, however, not included here is this study, such as crop yield and organoleptic qualities, will need to be integrated in selection programmes.

References

ANDRZEJEWSKA, I., 1967. Estimation of the effects of feeding on the sucking insect, *Cicadella viridis* L. (Homoptera: Auchenorrhyncha) on plants. In *Secondary Productivity of Terrestrial Ecosystems (Principles and methods)*, Poland Academic Science Institute of Ecology, Vol. 2, pp. 791–806.

AUCLAIR, J. L., 1989. Host plant resistance. In *Aphids: their Biology, Natural Enemies and Control* (A. K. Minks and P. Harrewijn, Eds) (Amsterdam: Elsevier), Vol. 3C, pp. 225–265.

BARLOW, C. A. and MESSMER, I., 1982. Pea aphid (Homoptera: Aphididae) induced changes in some growth rates of pea plants. *Journal of Economic Entomology*, **75**, 765–768.

BARLOW, C. A., RANDOLPH, P. A. and RANDOLPH, J. C., 1977. Effects of pea aphids, *Acyrtosiphon pisum* (Homoptera: Aphididae), on growth and productivity of the pea plants, *Pisum sativum. Canadian Entomologist*, **109**, 1491–1502.

BRINKMANN, R., OLDENBURG, S. and ZEBITZ, C. P. W., 1990. Einfluss-saugender insekten auf wachstum und wurzelleistung von gurke and ackerbohne. *Mitteilungen der Biologischen Bundesanstalt für Land und Fortswirtschaft*, **266**, 62.

CAUSTON, D. R. and VENUS, J. C., 1981. *The Biometry of Plant Growth* (London: Edward Arnold).

COCK, J. H., 1979. A physiological basis of yield loss in cassava due to pests. Cassava Program, (CIAT, Cali, Colombia), pp. 9–16.

DIXON, A. F. G., 1971a. The role of aphids in wood formation. I. The effect of the sycamore aphid, *Drepanosiphon platanoïdes* (Schr.) (Aphididae) on the growth of sycamore, *Acer pseudoplatanus* (L.). *Journal of Applied Ecology*, **8**, 165–179.

DIXON, A. F. G., 1971b. The role of aphids in wood formation. II. The effect of the lime aphid, *Eucallipterus tiliae* (L.) (Aphididae), on the growth of lime, *Tilia × vulgaris* (Hayne). *Journal of Applied Ecology*, **8**, 393–399.

EL-SHARKAWY, M. A. and COCK, J. H., 1987. Response of cassava to water stress. *Plant and Soil*, **100**, 345–360.

HAMMER, G. L., 1980. Estimation of cassava leaf area by a simple, non-destructive field technique. *Journal of the Australian Institute of Agricultural Science*, pp. 61–62.

HAWKINS, C. D. B., ASTON, M. J. and WHITECROSS, M. I., 1985. Aphid-induced changes in growth indices of three leguminous plants: unrestricted infestation. *Canadian Journal of Botany*, **63**, 2454–2459.

HAWKINS, C. D. B., WHITECROSS, M. I. and ASTON, M. J., 1986. Interactions between aphid infestation and plant growth and uptake of nitrogen and phosphorus by three leguminous host plants. *Canadian Journal of Botany*, **64**, 2362–2367.

HORBER, E., 1980. Types and classification of resistance. In *Breeding Plants Resistant to Insects* (F. G. Maxwell and P. R. Jennings, Eds) (New York: Wiley), pp. 683.

IHEAGWAM, E. U., 1981. Natural enemies and alternative hostplant of the cassava mealybug *Phenacoccus manihoti* (Homoptera: Pseudococcidae) in southeastern Nigeria, *Revue de Zoologie Africaine*, **95**, 433–438.

JIMENEZ, H. O., CADDEL, J. L. and BERBERET, R. C., 1988. Selection and characterization of tolerance to the spotted alfalfa aphid (Homoptera: Aphididae) in Alfalfa. *Journal of Economic Entomology*, **81**, 1768–1774.

JIMENEZ, H. O., CADDEL, J. L., BERBERET, R. C. and McNEW, R. W., 1989. Indices of plant damage and heritability of tolerance to the spotted alfalfa aphid in Alfalfa. *Crop Science*, **29**, 1337–1340.

LE RÜ, B., TERTULIANO, M. and CALATAYUD, P. A., 1991a. Les différentes catégories de résistance des plantes-hôtes de la cochenille du manioc *Phenacoccus manihoti* (Hom. Pseudococcidae): *Perspectives d'études. Résumé du 4ème Atelier du Réseau CORAF Manioc: Biocénose des principaux ravageurs du manioc et lutte biologique*. IITA-Bénin-Cotonou, 4–9 March 1991. (In press).

LE RÜ, B., IZIQUEL, Y., BIASSANGAMA, A. and KIYINDOU, A., 1991b. Variations d'abondance et facteurs de régulation de la cochenille du manioc *Phenacoccus manihoti* (Hom. Pseudococcidae) cinq ans après l'introduction d'*Epidinocarsis lopezi* (Hym., Encyrtidae) néotropical au Congo en 1982. *Entomophaga*, **36**(4), 499–511.

MALLOTT, P. G. and DAVY, A. J., 1978. Analysis of effects of the bird cherry oat aphid on the growth of barley, unrestricted infestation. *New Phytologist*, **80**, 209–218.

NEUENSCHWANDER, P., SCHULTHESS, F. and MADOJEMU, E., 1986. Experimental evaluation of the efficiency of *Epidinocarsis lopezi*, a parasitoïd introduced into Africa against the cassava mealybug *Phenacoccus manihoti*. *Entomologia experimentalis et applicata*, **42**, 133–138.

PRÜTER, C. and ZEBITZ, C. P. W., 1991. Effects of *Aphis fabae* and *Uromyces viciae-fabae* on the growth of a susceptible and an aphid resistant cultivar of *Vicia faba*. *Annals of Applied Biology*, **119**, 215–226.

SCHULTHESS, F., BAUMGÄRTNER, J. U., DELUCCHI, V. and GUTIERREZ, A. P., 1991. The influence of the cassava mealybug, *Phenacoccus manihoti* Mat. Ferr. (Hom. Pseudococcidae) on yield formation of cassava, *Manihot esculenta* Crantz. *Journal of Applied Entomology*, **111**, 155–165.

SCOTT, R. A., WORRALL, W. D. and FRANK, W. A., 1991. Screening for resistance to russian wheat aphid in triticale. *Crop Science*, **31**, 32–36.

WEBSTER, J. A., BAKER, C. A. and PORTER, D. R., 1991. Detection and mechanisms of russian wheat aphid (Homoptera: Aphididae) resistance in barley. *Journal of Economic Entomology*, **84**, 669–673.

WELLINGS, P. W., WARD, S. A., DIXON, A. F. G. and RABBINGE, R., 1989. Crop loss assessment. In *Aphids: their Biology, Natural Enemies and Control* (A. K. Minks and P. Harrewijn, Eds) (Amsterdam: Elsevier) Vol. 3C, pp. 49–64.

WILLIAMS, R. F., 1946. The physiology of plant growth with special reference to the concept of net assimilation rate. *Annals of Botany (London)*, **10**, 41–72.

WU, A. and THROWER, L. B., 1981. The physiological association between *Aphis craccivora* Koch and *Vigna sesquipedalis* Fruw. *New Phytologist*, **88**, 89–102.

Le Rü Bruno, Tertuliano Moukaram (1993)

Tolerance of different host-plants to the cassava mealybug Phenacoccus manihoti Matile-Ferrero(Homoptera : Pseudococcidae)

International Journal of Pest Management, 39 (4), 379-384

ISSN 0967-0874