Insect pests encountered in a citrus orchard in Nigeria

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Abstract — Introduction. The lack of good horticultural practices which minimises pest and disease attack and ensures vigorous plant growth is believed to contribute to citrus decline in many parts of Nigeria. A study was therefore undertaken to investigate the contribution of insect pests to this citrus tree loss. **Materials and methods**. Three citrus plots with die-back problems, located in an orchard in Nigeria, were studied: a progeny garden with diverse citrus types, a sweet orange variety trial and two rootstock trials. Leaves, twigs and fruits were sampled for insect pest infestation from randomly selected citrus trees. Termite infestation level was rated based on the extent with live termite galleries and the number of fruits dropped beneath a tree was noted. **Results**. Important insect pests were identified as termites, leaf miners, scale insects, and fruit flies. Termites and scale insects significantly contributed to the die-back of citrus plants. The sweet orange variety Washington navel was most susceptible to insect pest attack. The incidence of fruit fly was widespread and caused damage to marketable citrus fruits. In the rootstock trials, Rough lemon rootstocks was highly attacked by termites, especially those budded with Lake tangelo. **Discussion**. Termites and scale insects are likely to contribute to quicker decline in some citrus varieties than in others as shown by the high susceptibility of Washington navel to pest attacks. Such cases may be aggravated by the use of a rootstocks unsuitable for an area which are constantly under high disease and pest pressure. (© Elsevier, Paris)

Nigeria / *Citrus* / variety trials / pest insects / damage / pest resistance

Insectes nuisibles observés dans un verger d'agrumes au Nigéria.

Résumé — Introduction. Le manque de pratiques horticole adéquates aptes à limiter les dégâts occasionnés par des insectes nuisibles et autres maladies et à assurer une croissance vigoureuse des arbres aurait contribué à la disparition d'agrumes dans plusieurs régions du Nigéria. Une étude a donc été entreprise pour identifier le rôle des insectes dans cette destruction des arbres. **Matériel et méthodes**. Trois parcelles d'agrumes localisées dans un verger du Nigéria et présentant des problèmes de dépérissement ont été étudiées : une pépinière constituée de divers types d'agrumes, une expérimentation testant différentes variétés d'orangers et une autre testant différents porte-greffes. Les feuilles, rameaux et fruits d'arbres choisis au hazard ont été échantillonnés afin d'évaluer leur degré d'infestation par des insectes. L'attaque par les termites a été évaluée à partir d'une échelle de notation basée sur l'étendue des galeries observées, et le nombre de fruits tombés a été noté. **Résultats**. Les principaux insectes nuisibles identifiés ont été les termites, les chenilles mineuses de feuilles, les cochenilles et les mouches de fruits. Les termites et les cochenilles se sont avérées contribuer significativement au dépérissement des agrumes. L'oranger Washington navel a été le plus sensible aux attaques des insectes nuisibles. Les mouches de fruits, très répandues, ont causé des dégâts aux fruits commercialisables. Dans les essais de portes-greffes, Rough Lemon a été très attaqué par les termites, surtout lorsque greffé avec la varieté « Lake tangelo ». **Discussion**. Au Nigéria, les termites et les cochenilles ont probablement contribué au dépérissement de certaines variétés d'agrumes plus qu'à d'autres, comme en témoignerait la grande sensibilité aux attaques des nuisibles, observée pour l'oranger Washington navel. Cette situation a pu être aggravée par l'utilisation de porte-greffes inadéquats dans un environnement soumis à une forte pression parasitaire. (© Elsevier, Paris)

Nigéria / *Citrus* / essai de variété / insecte nuisible /dégat / résistance aux organismes nuisibles

1. introduction

Citrus is one of the most widely grown vitamin-rich fruit crops in Nigeria. It is consumed fresh, as juice, or in confectionery and marmalade. Production statistics on this useful crop have not been updated over so many years in Nigeria due to dwindling research activities on it. About a decade ago, production was estimated at 25 000 t a year from 2 500 ha [1]. However, funding has been increased in recent years for citrus research with the aim of significantly increasing production. In many parts of Nigeria, citrus orchards have been experiencing serious decline due to pests and diseases. Such problems are sometimes accentuated by nutritional deficiencies and old age of the plants. Preliminary studies in some parts of Nigeria showed the involvement of several insect pests and diseases in citrus damage, of which economically important insects include termites, scale insects, leaf miner, fruit piercing moths, fruit flies and aphids [1, 2].

In Nigeria, there are variations in the abundance of insects in relation to citrus phenology. Generally, the leaf feeders such as the leaf miners, *Papilio demodocus*, and grass hoppers fluctuate from high in the wet season (June–October), when new flushes are abundant, to low in the dry season (November to the following May). However, in the study area, which is located in the humid forest vegetative zone of southwestern Nigeria (maximum annual rainfall of 1 800 mm), the rainy season starts earlier. Prior to the rainy season, sporadic off-season rains also contribute to the production of new flushes. Therefore, attack by leaf feeders persists during the year. Herbivores such as grass hoppers *Zonocerus variegatus* L., which are polyphagous and highly damaging in the dry season to cassava cropping systems (predominant in the area), also attack citrus at the same period. Grass hoppers, leaf miners and *P. demodocus* are often more important as pests of young citrus transplants and nurseries throughout the year.

Fruit feeders are more abundant during early and late blooming/fruiting periods. However, it should be recognised that the abundance and damage by citrus insect pests vary from one year to another and are more or less related to changes in climatic conditions which are not stable in the tropics.

Termites (Isoptera) can attack citrus from seedling to mature stages usually under cover of foraging galleries recognised externally by soil sheets that cover the attacked parts [3, 4]. Attack is often enhanced by low plant vigour caused by other pest and disease damage as well as nutritional deficiencies [5]. In a survey in citrus producing areas in Nigeria, the authors observed that termite damage was also associated with trees infected by the foot and brown rot gummosis. The later observation was therefore investigated in the present study.

Scale insects (Homoptera: Coccidae) are world-wide known to be serious pests of citrus. They persist throughout the year due to their multivoltinity (several generations per annum) [6], although they are often more abundant in the rainy season. They feed on leaves, twigs, and fruits and their damage often leads to morphological deformation or death of the affected part or of the entire plant.

The citrus leaf miner (Lepidoptera: Phyllocnistidae) is another group of insects increasingly becoming of economic importance in citrus orchards in many parts of the world [7] including Nigeria. Damage is caused by their larvae which destroy the adaxial and abaxial surfaces of newly formed leaves by making serpentine tunnels called mines. Damage at advanced stage is also characterised by twisted and malformed leaves which may drop prematurely [8]. Leaf miners also undergo several generations per year, and are thus present in citrus throughout the year under favourable conditions.

Attack by the fruit piercing insects are among the direct causes of fruit losses in citrus production. Although they do not

cause die-back in citrus, up to 70% of set fruits may be lost to the combined attack of these insects [2] during severe infestation. The mediterranean fruit fly *Ceratitis capitata* Wiedmann, for example, is a major agricultural pest in many countries of the world [9, 10]. Female flies pierce fruits to lay their eggs. The emerging larvae then feed on fruit pulp, thus rendering the latter undesirable. Fruit piercing moths are principally noted for causing premature fruit drop due to their piercing action. The various damages by fruit piercing insects render fruits unmarketable and predispose fruits to entry by rot-causing fungi. The lack of adequate citrus maintenance culture and non-application of control measures against pests and diseases by most of the growers may have contributed to yield losses and the continuous citrus decline observed in Nigeria.

A recent survey in established orchards of Nigeria showed that the most important and commonly observed diseases included:

– the viral diseases tristeza (quick decline) transmitted by a vector aphid (*Toxoptera citricidus* Kilkaldy) and citrus greening transmitted by citrus psyllid vectors (*Trioza erytreae* del Guercio, and *Diaphorina citri* Kuwayana), budding and grafting;

– the fungal diseases foot rot and brown rot gummosis caused by *Phytophthora citrophthora* and *P. parasitica*, and Rubellosis disease caused by a fungi *Corticium salmonicolor* (Umeh et al., unpubished); these diseases have been previously reported by other authors in earlier studies [1, 11].

High pest damage often results in die-back of infested citrus plants. With a complex mixture of pest and disease species and its associated high population density, the pressure on plants are often so high that die-back may progress at a fast rate leading to the eventual death of the plant [1].

None previous work being available in the literature on the relationship between citrus varieties or rootstocks and major insect pest damage in Nigeria, the present study aimed specifically at identifying insect pest species of economic importance to citrus, and the relationship between their infestation levels and die-back. The most cultivated citrus varieties and rootstocks commonly used in the country were considered. However, the relationship between root rot disease (gummosis) and termite damage was also investigated in the light of mixed attacks (gummosis/termite) often observed and the resultant citrus decline. Based on a nation-wide survey conducted in 1994, by the authors, in the Nigeria citrus producing areas, the major insect pests were found to be distributed all over the nation at varying incidence levels. Therefore, a citrus orchard, belonging to the National Horticultural Research Institute (NIHORT) and located nearby Ibadan in the humid forest vegetative zone of southwestern Nigeria, was used for the study. The orchard, constituted with the major varieties and rootstocks planted in the country, was made up of various trials with die-back problems, including a progeny garden with diverse citrus types, a sweet orange variety trial and two rootstock trials.

2. materials and methods

2.1. insect pests *in citrus* progeny garden

Solid blocks of ten citrus types were used for the study and included the sweet oranges: Agege-1, King orange, Parson Brown, Valencia and Washington navel; the tangelos: Lake and Minneola; and mandarin, Rough lemon and Duncan grapefruit.

Stratified random sampling was applied to each solid block made up of a citrus type and divided into six equal portions. In each portion, one citrus tree was randomly sampled, and thus totalling six sampled trees per citrus type. Each citrus tree was considered as a sampling unit on which insect pest species and damage was assessed as described below.

2.1.1. citrus infestation and damage in the progeny garden

The levels of infestation of leaves, twigs and fruits by insect pests were assessed between January and February 1995, when mature fruits were abundantly present and insect attacks on leaves were still widespread due to new flushes. Such a period could allow to observe the diverse species of citrus pests at the same time.

Each sampled tree was divided into a lower and upper canopy (within a clear visible limit).

A leaf in each of five points along the circumferences of the two portions were sampled, thus totalling 10 sampled leaves/tree. Infestation levels of each insect species was rated according to the number of leaves infested per tree from the total. At each sampling point, observation was made on the branch or twig supporting the sampled leaf for the incidence of die-back and was scored (with a maximum infestation level of 10) as above.

Damage caused by fruit flies and fruit piercing moths was assessed by harvesting one mature fruit from each of five points in the two portions of the divided canopy, and observing dissected sections of these fruits with a hand lens in the laboratory. Developmental stages of fruit flies were reared to adult by keeping maggot-infested fruits in cages. Fruit fly infestation level was thus scored from a total of 10 points. Since infestation levels were scored based on the number of damaged fruits observed in the ten points, traps baited with trimedlure traditionally used in fruit fly population studies were not used. Visits were made to the orchard at dusk, when infestations usually occur, to confirm the identity of fruit piercing moths.

Levels of fruit drop were scored by counting the number of fallen fruits underneath each sampled tree and were rated as follows: none: 0; 1–10: 1; 11–20: 2; 21–30: 3; 31–40: 4; > 40: 5. These fruits were inspected for the presence of insects.

2.1.2. assessment of termite infestation and damage

Termite infestation level was based on observing the extent of active gallery coverage of the trees or ramification of active galleries on the trees. Galleries were opened at different points on the trees to identify the termite species and damage done.

For termites that do not build tree mounds (e.g., *Macrotermes* and *Coptotermes* species), infestation level was rated per tree as follows: no visible attack: 0; presence of galleries in the trunk base: 1; presence of galleries in the trunk base to 1/2 of the trunk: 2; presence of gallery on the whole tree trunk: 3; presence of gallery on the trunk and parts of main branches: 4; presence of gallery in the trunk and all the main branches: 5.

For arboreal (i.e., with tree mounds) termites (*Nasutitermes* and *Microcerotermes* species), infestation level was rated as follows: no gallery: 0; gallery present in the trunk: 1; galleries present in the trunk and < 1/4 of the main branches: 2; gallery present in the trunk and < 1/4 of branches, and presence of arboreal mounds: 3; gallery present in the trunk and 1/4 to < 1/2 of the main branches, and presence of arboreal mounds: 4; gallery present in trunk and > 1/2 of the main branches, and presence of arboreal mounds: 5. It should be noted that presence of arboreal mounds implies an established colony.

At the beginning of the rainy season (in late April 1995), when the ground was relatively soft, soil samples were taken in the progeny garden with an auger from depths of 30 cm and 10 cm diameter in the immediate surrounding of each sampled tree. Insect samples, manually separated from the soil and counted, were collected for identification in the laboratory.

2.2. infestation of sweet orange varieties by insect pests

The field layout of the trial was a randomised complete block design of four

blocks; each block contained a set of three trees of each variety. Foreign varieties included Carter navel, Hamlin, Lue Gim Gong, Meran, Parson Brown, Pineapple, Valencia late, and Washington navel, while the local varieties were Agege-1, Bende, Etinam, and Umudike. Cleopatra mandarin was used as rootstock for all the varieties. One tree was sampled per variety in each block. Insect pest infestations were assessed on each tree using the methods already described for the progeny garden study.

2.3. assessment of termite attack on rootstock trials

Separate trials with Lake tangelo and the Agege-1 sweet orange variety, budded on six rootstocks, were laid out in a randomised complete block design with four replications. In the two trials, each block contained a set of three trees of each of the tested rootstocks randomly distributed. For Lake tangelo, the rootstocks were Cleopatra mandarin, Panderosa and Rangpur limes, Rough lemon, sour orange and Swinglea. For Agege-1, the same rootstocks were used but Duncan grapefruit was substituted for Swinglea. In each block, a tree per set of rootstock was sampled. Termite infestation levels and die-back of branches were assessed following the methods described for the progeny garden trials. Gummosis (a gum disease caused by *Phytophthora* spp.) was scored as present or absent.

2.4. statistical tests

Analysis of variance (ANOVA) was conducted for variables that contributed to citrus damage in the randomised complete block design. Means of significantly different variables were separated using Duncan Multiple Range Test. All statistical analyses were computed using SAS program [12].

A multiple regression analysis was conducted with the infestation levels of the major pests encountered to assess their contribution to citrus die-back. For doing this study, the infestation levels of the various termite species were pooled for each citrus variety (since they cause similar damage).

3. results

3.1. citrus insect species encountered

Several species of insects were identified on citrus (*table I*). Some were widely distributed while others were only occasionally observed.

The predominant species were the termites *Macrotermes subhyalinus* Rambur and *M. bellicosus* Smeathman (= *nigeriensis* Sjostedt), and the citrus leaf miner

Table I.
Insect pests encountered in a citrus orchard in Ibadan, Nigeria.

Insect pest species	Part(s) of citrus attacked
Isoptera	
Macrotermes bellicosus Smeathman	Trunk, branches, parts of roots
Macrotermes subhyalinus Rambur	Trunk, branches, parts of roots
Coptotermes sjostedti Holgren	Trunk, branches, parts of roots
Nasutitermes arborum Smeathman	Trunk and branches
Microcerotermes fruscotibialis Sjöstedt.	Trunk and branches
Lepidoptera	
Phyllocnistis citrella Stainton	Leaves
Papilio demodocus	Leaves
Achaea linardi	Fruits
Homoptera	
Parlatoria pargandii Comstock	Leaves, twigs
Lepidosaphes gloverii Pack	Leaves, twigs
Lepidosaphes beckii Newman	Leaves, twigs
Diptera	
Ceratitis capitata Weid.	Fruits
Hymenoptera	
Oecophylla longinoda Latreille	All over tree, fold leaves
Crematogaster sp.	All over tree
Dorylus sp.	All over tree
Orthoptera	
Zonocerus variegatus L.	Leaves
Hemiptera	
Annoplocnemis curvipes Fabricius	Leaves, fruits
Leptoglosus membranaceus Fabricius	Leaves, fruits

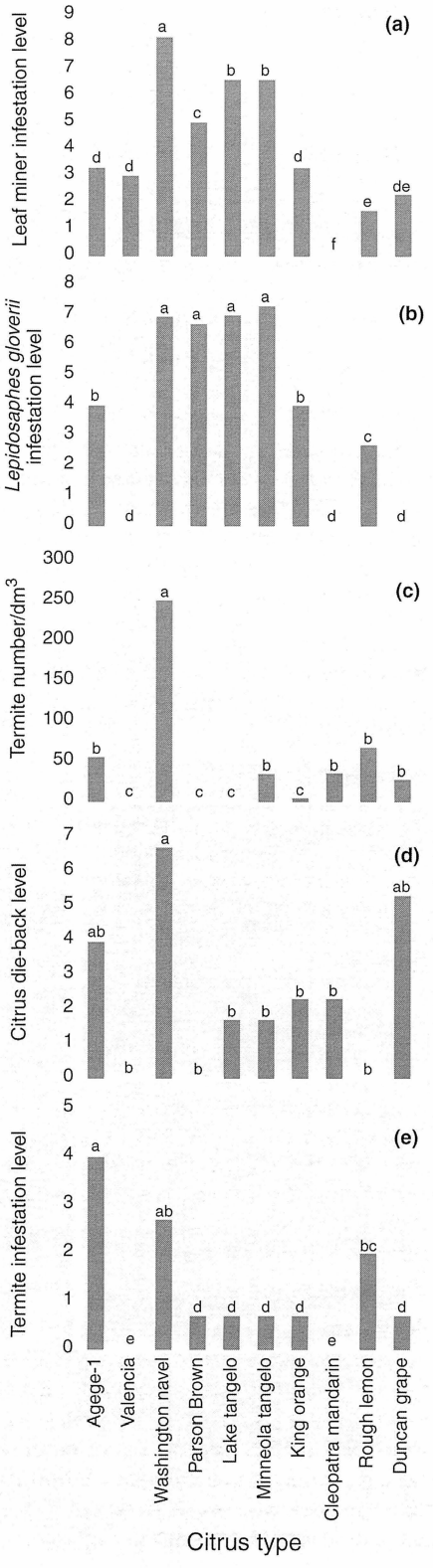

Figure 1.
Comparison of citrus insect pest infestation levels (number of samples affected over 10 samples) according to 10 citrus types included in a Nigeria orchard.
(a) leaf miner infestation;
(b) scale insect infestation;
(c) mean population densities of *Macrotermes* in the surrounding soils of the citrus types;
(d) citrus die-back level;
(e) termite infestation.

Phyllocnistis citrella Stainton. The scale insects included *Parlatoria pergandii* Comstock (chaff scale), *Lepidosaphes gloverii* Pack (long scale), and *Lepidosaphes beckii* Newman. The fruit fly, *Ceratitis capitata* Wiedemann, predominantly accounted for most of fruit losses, while damage of fruits by the fruit piercing moth *Achaea linardi* was comparatively low. It was not uncommon to encounter tailor ants, *Oecophylla longinoda* Latreille, folding leaves of citrus trees.

3.2. citrus insect pest infestation in the progeny garden

Leaf miner *P. citrella* occurred in 68.3% of citrus trees in the progeny garden. Infestation level was highest on Washington navel followed by Lake and Minneola tangelos (*figure 1a*). Attacked leaves appeared shrunken and stunted with reduced photosynthetic areas. Cleopatra mandarin was not infested, while the infestation level observed on Rough lemon was low. The contribution of leaf miner infestation to die-back of trees was low and insignificant when included in a multiple regression with other factors.

Citrus leaves and twigs were more infested by nymphs and adult females of the long scale *L. gloverii* than by the chaff scale *P. pergandii*. The latter was observed at low levels on leaves of Agege-1, Minneola tangelo, Parson Brown, and Washington navel, while *L. gloverii* generally occurred at a very high level on attacked plants and severely damaged citrus leaves and twigs of all sampled citrus types, except Cleopatra mandarin, Duncan grapefruit and Valencia which were not attacked (*figure 1b*). However, the infestation level of *L. gloverii* on Rough lemon was relatively low. The number of scales on some leaves was so high and clustered that counting was discontinued due to the vast area of the orchard to be sampled. Interplant aggregation on leaves per scale insect species varied considerably for each citrus species. On a tree, approximately, an average of 20 scale insects per leaf was observed. Also observed on twigs, they were yet to attack the fruits.

There was a mutual relationship between the ant *Crematogaster* sp. and the scale insects. The latter were tended by ants that, in turn, benefited from the honey dew secreted by the scale insects. The incidence of other leaf pests such as *Zonocerus variegatus* and *Papilio demodocus* was very low and non-significant.

With the exception of fruits of King orange and Rough lemon, fruit of other citrus types were mostly attacked by the fruit fly, *C. capitata,* and only occasionally by the fruit piercing moth, *Achaea linardi*. Observations made on moths attacking fruits by visiting the orchard at dusk indicated that punctures made on fruits also elicited fruit drops. Fruit fly larvae and adults were widely encountered in 80% of the sampled trees, both in fruits sampled on trees and those on the ground. Their attack was mostly observed on fully ripe fruits which were positioned in the lower to middle part of the canopy. Damage by other fruit piercing insects such as *Anoplocnemis curvipes* Fabricius and *Leptoglossus membranaceus* F. was negligible.

3.3. soil pests in the citrus progeny garden

M. subhyalinus and *M. bellicosus* attacked all citrus types and were identified in 28% of the sampled trees. *Nasutitermes arborum* Smeathman and *Microcerotermes fruscotibialis* Sjöstedt were also identified on all citrus types, but infestation by these species accounted for only 13.3 and 11.7% of sampled trees, respectively. *Microcerotermes* was mostly on Parson Brown and Washington navel, and, with *Macrotermes*, excavated the woody tissues of trunks and branches of trees. *N. arborum* was only observed on Washington navel whereby they scarified extensively the bark of the latter. Mean population density of *Macrotermes* species in soil samples from near Washington navel was higher (251 individuals/dm^3) than those from the surroundings of other citrus types (*figure 1c*). Termites contributed significantly ($P < 0.001$) to die-back ($r^2 = 0.466$), observed to be most severe on Washington navel, Duncan grape fruit, and Agege-1 (*figure 1d*). The highest termite infestation levels were noted on Agege-1, Washington navel and Rough lemon, respectively, when the mean infestation levels of the termite species were pooled (*figure 1e*). When the pooled mean infestation levels of scale insects were included in multiple regression analysis with levels of factors such as termites and leaf miners ($r^2 = 0.488$), a significantly high contribution to die-back was observed ($r^2 = 0.850$; $t = 10.426$).

Ants identified from the citrus types included the African driver ant *dorylus* and *crematogaster* species, and the tailor ant *Oecophylla longinoda*. The latter was widespread and folded many citrus leaves together to make their nests. They did not seem to play any direct role in citrus die-back.

3.4. insect pests on sweet orange varieties

With the exception of Pineapple and Meran varieties, which were significantly ($P < 0.05$) least infested, all varieties were highly infested by leaf miners (*figure 2a*). However, leaf distortion characteristic of high leaf miner damage was only observed on Washington and Carter navels, and Hamlin.

The scale insect *L. gloverii* was observed on sweet orange varieties, with the highest infestation levels recorded on Washington navel and Bende, followed by Parson Brown (*figure 2b*). *P. pergandii* and *L. beckii* infestations were only observed, at low levels, on Washington navel and Bende varieties.

Washington navel was most susceptible to *Macrotermes* attack (*figure 2c*). Despite the low incidence of *Nasutitermes* and *Coptotermes* compared to *Macrotermes*, their damage was most pronounced on Washington navel whereby the tree trunks were excavated. Multiple regression analysis of die-back levels against the pooled mean infestation levels of termites and other insect pest species

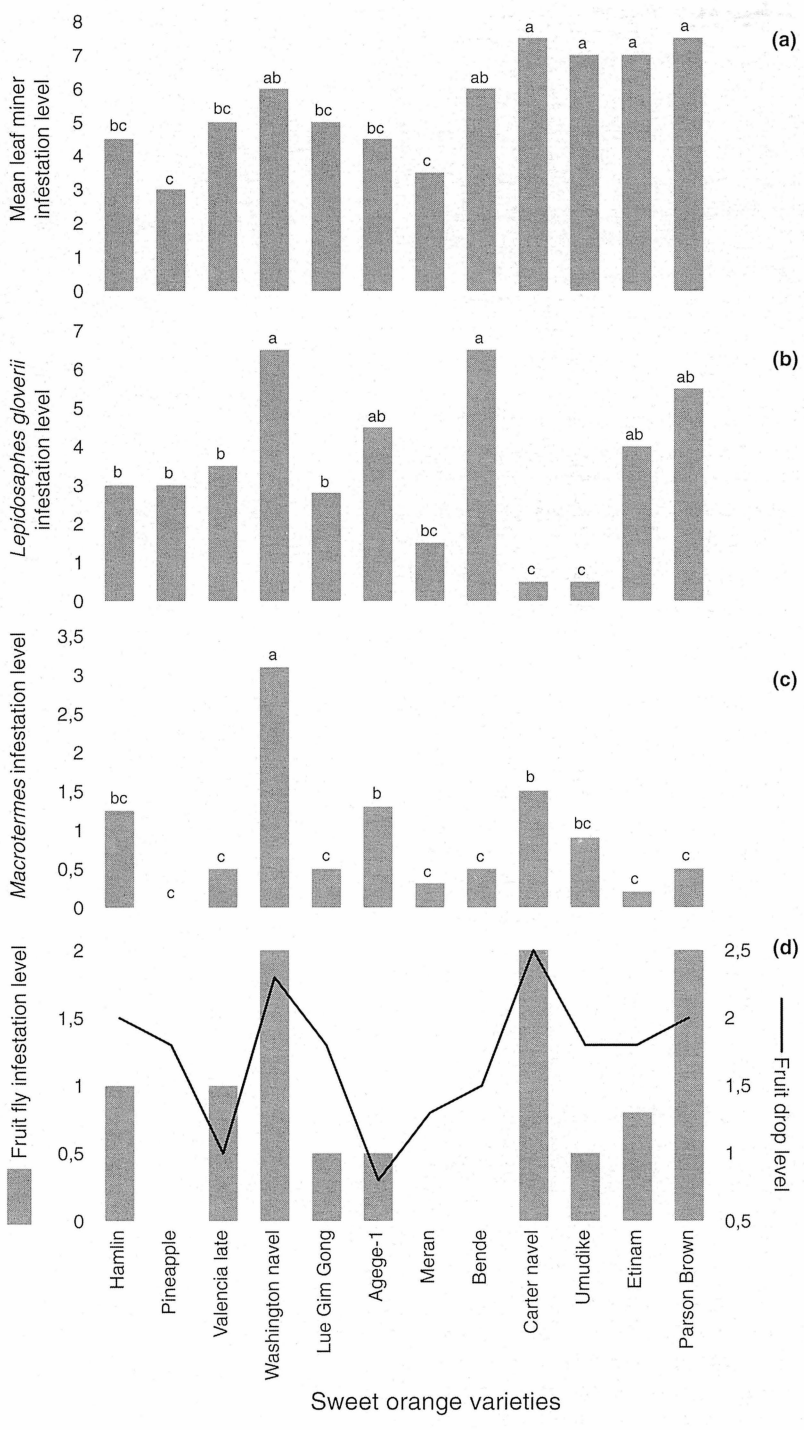

Figure 2.
Comparison of mean infestation levels (number of samples affected over 10 samples) according to 12 sweet orange varieties of a Nigeria orchard for:
(a) leaf miners; (b) scale insects; (c) termites;
(d) fruit flies presented with the corresponding fruit drop levels.

indicated that only termites significantly contributed to die-back (r^2 = 0.38; t = 0.46; $P < 0.001$). A stand each of Washington and Carter navels found to be attacked by termites was infected by foot rot gummosis disease caused by *Phytophthora* spp.

Ant species identified from citrus and soil samples were *Oecophylla*, *Dorylus* and *Crematogaster* species. *Crematogaster* tended scale insects by carrying them to other parts of the trees, while *Oecophylla* folded leaves of the orange varieties to construct nests. *Dorylus* was observed moving on the infested trees, especially on those with high presence of scale insects, without any apparent damage. It was suspected to be tending scale insects as well.

Attack on fruits by the fruit flies was significantly higher on Parson Brown, Washington and Carter navel varieties despite the generally low infestation levels observed on all varieties (*figure 2d*). Only few occurrences of damage by the fruit piercing moths were observed (< 15%). Ripe fruits located at the lower part of the trees were more attacked by fruit flies than those higher up in the canopy. Fruit drop was found to be high in the most susceptible varieties (*figure 2d*) with more than 50% of the dropped fruits harbouring fruit flies. Fruit drop was significantly ($P < 0.05$) correlated with fruit fly infestation level (r = 0.6; n=12).

3.5. termite attack on rootstock trials

Only infestation by *Macrotermes* and *Nasutitermes* species was of economic importance in the two rootstock trials.

In the Lake tangelo rootstock trial, the infestation level was significantly higher with the Rough lemon and Panderosa lime rootstocks than with the other rootstocks (*figure 3a*). In this trial, gummosis disease caused by *Phytophthora* spp. was observed on 15% of the sampled trees, but was totally absent on Lake tangelo budded with Cleopatra mandarin rootstock; termite infestation was only

slightly correlated with die-back (r^2 = 0.32; $P < 0.05$).

In the Agege-1 rootstock trial, a generally low mean infestation levels (*figure 3b*) was observed and no significant difference occurred between the tested rootstocks. Gummosis occurred in 12% of the sampled trees of which 75% were attacked by termites.

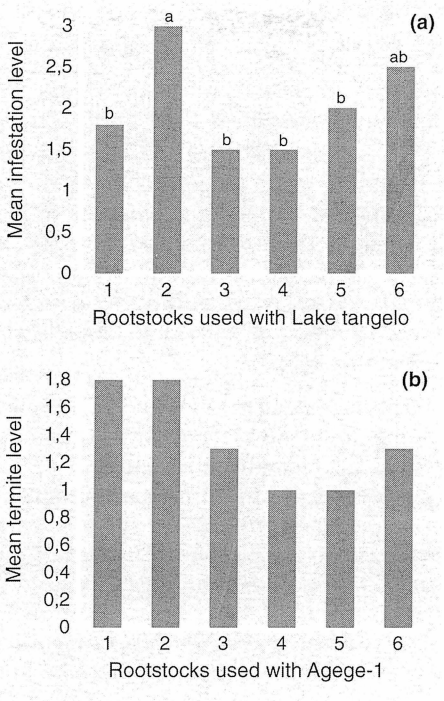

Figure 3.
Effect of six rootstocks:
1: Cleopatra mandarin;
2: Rough lemon;
3: Swinglea for Lake tangelo and Duncan grapefruit for Agege-1;
4: Rangpur lime;
5: Sour orange;
6: Panderosa lime on termite attacks of two varieties of sweet orange:
(a) Lake tangelo;
(b) Agege-1.

4. discussion

The highest attack by the leaf miner (*P. citrella*) observed on the citrus types Washington navel and the tangelos probably suggested its preference for their leaves. This was further demonstrated in the sweet orange varietal trial whereby leaf distortion characteristic of severe leaf miner attack [13] was observed only on the exceptionally sweet varieties such as Washington and Carter navels, and Hamlin, despite the infestation of other varieties. However, the factors that determined preference were beyond the scope of this study. Although the leaf miners did not significantly contribute to die-back, their reduction of leaf photosynthetic area, especially in distorted leaves, might lead to unnoticed abnormal changes in the plant. In infested areas, the citrus leaf miners are known to attack all varieties of citrus with new flush [14]. Immediate past surveys of citrus producing areas, carried out by the authors in 1994, showed that Washington navel and the tangelos had relatively higher leaf miner infestation compared to other varieties as observed in this study.

The three species of scale insects identified were so highly aggregated on leaves and twigs that counting the number of individuals per leaf during sampling was not feasible due to the large number of samples to be taken. However, infestation levels scored on the basis of points of attack showed that scale insects contributed significantly to the die-back of citrus varieties. The most prevalent scale insect was the long scale, *L. gloverii*, followed by the chaff scale, *P. pargandii*, whose infestation level was comparatively lower. Occurrence and attack of citrus by *L. beckii* was negligible. Eguagie [6] reported that the degree of aggregation varies with the species of scale insects; using Taylor's [15] power law, 'b', he noted that aggregation on citrus leaves decreased from *L. beckii* (1.9) to *P. pergandii* (1.75) to *L. gloverii* (1.15). In a nation-wide survey of producing areas carried out by the authors, scale insect species dominance varied from one field to another. However, as for the present studies, scale insect preference for Washington navel and the tangelos was generally observed especially in the middle belt region of Nigeria (highest citrus producing area) irrespective of which species was dominant. The most infested varieties in the present study – Washington navel and Minneola tangelo – were noted as having the densest canopy spread in the orchard, which allowed for a physical contact between the canopies and facilitated easier dispersal of scale insects between neighbouring branches by ants such as *Crematogaster* sp. (since these scale insects are relatively static). *Cre-*

matogaster tends scale insects [16, 17]) and often carries them to new branches while benefiting from their secretions. Beside attracting ants, such secretions enhance the formation of sooty moulds [18]. Doryline ants were also suspected to be tending scale insects and benefiting from their secretions since these ants predominantly occurred on trees infested by scale insects. The contribution of *O. longinoda* to citrus damage was not detected, except for their ability to fold citrus leaves for nesting purposes.

The higher affinity shown by termites for the sweet citrus types Washington and Carter navels, and the Tangelos (also observed with other major insect pests), indicated that preference was governed by certain factors not investigated in this study. The population density of *Macrotermes* species which caused most of the observed damage in the progeny garden was also highest in the immediate surrounding soils of Washington navel which had the highest termite infestation level. An earlier study conducted by Sands [3] on termites destructive to trees and crops in northern Nigeria showed that most of citrus damage was caused by *Macrotermes* species, while *Odontotermes* damage was only observed on rare occasions. The present study showed that, apart from *Macrotermes* species, other genera such as *Coptotermes*, *Nasutitermes*, and *Microcerotermes* (not previously associated with citrus damage in Nigeria) could also contribute to damage, and thus add to the overall pest/disease damage which results in die-back. Although citrus variety preference by termites has not been investigated in Nigeria, the contribution of *Macrotermes* species to citrus decline is now well established. Furthermore, these results emphasise the need for necessary precautions to be taken when establishing new orchards in termite-infested fields, especially with highly susceptible citrus varieties. The attack of a tree by *Macrotermes* species as well as its presence in the immediate surrounding soil of such tree often implies that the root system may have been attacked. It is therefore most likely that citrus roots could have been attacked (in the case of Washington navel), and thus contribute to the observed citrus decline. Although most termite damage on citrus was caused by *Macrotermes*, there were instances whereby the combination of *Macrotermes* and the fungi *Phytophtora* spp. contributed to damage. It was difficult to state which of the two (termite or fungus) initiated attack. A further study on the latter aspect will contribute significantly in designing a meaningful intervention against citrus die-back. It is known however that disease infections can lower plant vigour and enhance the susceptibility of a plant to termite attack. The contribution of termite in association with fungi to the spread of die-back on tree crops was first reported in Nigeria by Sands [3] on cocoa, *Theobroma cacao*, attacked by the termite *Neatermes aburiensis* Sjöstedti.

Termites did not cause as much damage in Agege-1 rootstock trial as in tangelo rootstock trial. In the latter however, those budded on Rough lemon were most damaged by termites, and sometimes with *Phytophthora* spp. infection, probably indicating the non-suitability of Rough lemon rootstock in the area. The choice of suitable citrus rootstocks for particular soils and vegetation zones is very important in maintaining plant vigour, minimising susceptibility to pest and disease attacks, and thus ensuring good plant growth. Evaluation trials by Matheron and Porchas [19] identified rootstocks with high degree of resistance to gummosis and root rot caused by *P. citrophthora* and *P. paradisi*. Part of NIHORT's long-term research plan on the development of citrus industry in Nigeria includes the evaluation of rootstocks in different parts of the country with a view to determine those suitable for the various ecological zones and soil types in terms of pest and disease resistance, and other beneficial agronomic attributes. The present study will therefore form a benchmark for future research on termite damage to citrus rootstocks.

The contribution of fruit piercing insects in the reduction of marketable citrus fruits was shown by their presence in majority of citrus types, of which fruits sit-

uated in the lower parts of the canopy and fully mature were mostly attacked by *C. capitata*. It has been reported that infestation by *C. capitata* varies according to the fruit locations on tree, fruit maturity and associated advanced ripeness [20, 21]. These factors are important in timing effective control period. The higher attack observed on fruits of Parson Brown, Washington and Carter navels in the sweet orange varietal trials may not be unconnected with their chemical characteristics at full ripening (not analysed in this study). The stage of fruit ripening is linked to its physical/chemical characteristics which render it more attractive to fruit fly oviposition. These include the level of essential oils in the fruit rind and the reduction in the acidity of the fruit rind and juice [20], and the nature of volatile substances in the fruit rind [22]. Ortiz et al. [23] reported that an increase in the sugar content of the fruit rind of Valencia Late, Washington navel and Navelate favoured fruit fly attack. Results of the present study showed that fruits of Rough lemon and King orange were not significantly attacked by the fruit flies or the fruit piercing moths. This was suspected to be associated with the thickness of the fruit rind in these citrus types which did not allow for easy penetration of insect mouth parts to the juicy portion as well as the physical/chemical characteristics of the fruit rind. The widespread presence of fruit flies in fruits found beneath trees could be detrimental to unharvested fruits since these dropped fruits act as reservoir for reinfestation of new fruits. Burying or burning these fallen fruits could be the easiest point to debut control measures against fruit flies. Although fruit damage by the fruit piercing moths, *A. linardi*, and the fruit bugs, *A. curvipes* and *L. membranaceus*, was not significant in this study, the severity of their attack varies from one season to another. In Nigeria, Babatola [2] attributed up to 70% fruit losses to fruit piercing insects. Termites, scale insects, and leaf miners were the major groups of insects affecting the survival of citrus stands in the four trials assessed. Although leaf miner damage may not directly affect the die-back of citrus, their reduction of the leaf photosynthetic area is likely to have an adverse effect on the physiological functioning of the plant. The contribution of insect pests to continuous citrus stand losses in the trials was more critical on some of the varieties than on others. Therefore, this study shows the relative importance of the observed insect pests to citrus decline by assessing their levels of infestation of plant parts. However, these results are expected to form basis for further investigations in areas of Nigeria where similar insect species are of economic importance in the presence of various citrus species.

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Insectos dañinos observados en un vergel de agrios en Nigeria.

Resumen — Introducción. La falta de practicas hortícolas adecuadas capaces de limitar los daños ocasionados por insectos dañinos y otras enfermedades y de asegurar un crecimiento vigoroso de los árboles hubiera contribuido a la desaparición de agrios en varias regiones de Nigeria. Por lo tanto, se ha emprendido un estudio para identificar el papel de los insectos en esta destrucción de los árboles. **Material y Métodos**. Se estudiaron tres parcelas de agrios ubicadas en un vergel de Nigeria y presentando problemas de marchitamiento: un vivero constituido de varios tipos de agrios, un experimento sometiendo a prueba distintas variedades de naranjos y otro sometiendo a prueba distintos porta-injertos. Se muestrearon las hojas, los ramos y frutos de árboles seleccionados al azar para evaluar su grado de infestación por insectos. El ataque por los comejenes fue evaluado a partir de una escala de notación basada en la amplitud de las galerías observadas y se apuntó el número de frutos desprendidos. **Resultados**. Los principales insectos dañinos identificados fueron los comejenes, las larvas minadoras de hojas, las cochinillas y las moscas de frutos. Los comejenes y las cochinillas resultaron contribuir significativamente al marchitamiento de los agrios. El naranjo 'Washington navel' fue el más sensible a los ataques de los insectos dañinos. Las moscas de frutos, muy comunes, provocaron deterioros en los frutos comercializables. En los ensayos de porta-injertos, 'Rough Lemon' fue muy atacado por los comejenes, sobre todo cuando injertado con la variedad 'Lake tangelo'. **Discusión**. En Nigeria, los comejenes y las cochinillas contribuyeron probablemente al marchitamiento de ciertas variedades de agrios más que de otras, como lo atestiguaría la gran sensibilidad a los ataques de los dañinos, observados para el naranjo 'Washington navel'. Esta situación pudo empeorarse al utilizar porta-injertos inadecuados en un entorno sometido a una fuerte presión parasitaria. (© Elsevier, Paris)

Nigeria / *Citrus* / ensayos de variedades / insectos dañinos / daños / resistencia a las plagas