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Importance of spittle bugs, *Locris rubens* (Erichson) and *Poophilus costalis* (Walker) on sorghum in West and Central Africa, with emphasis on Nigeria

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Summary

Locris rubens (Erichson) (Cercopidae: Homoptera) and *Poophilus costalis* (Walker) (Aphrophoridae: Homoptera) are endemic pests of sorghum (*Sorghum bicolor* (L.) Moench) in Nigeria and some other countries in West and Central Africa. Other hosts are maize, pearl millet, rice, sugarcane, and grasses. On sorghum, *L. rubens* lays eggs in the epidermis of the leaf sheath. There are five nymphal instars and development from egg to adult takes about 33 days. Both species of spittle bugs feed on all growth stages and all parts of sorghum, including the panicle. Feeding symptoms include yellow leaf blotching. Severe infestations often kill young leaves and plants. Under artificial infestation in cages, the severity of damage and associated symptoms as well as grain yield loss increased with an increase in the population density of spittle bugs. Infestation by 15 pairs of adult *L. rubens* over a period of 5 wk reduced grain yield by 35% in 1994. It is concluded that spittle bugs are important pests of sorghum in Nigeria.

Key words: Sorghum, spittle bugs, *Poophilus costalis*, *Locris rubens*, yellow leaf blotch, West Africa

Introduction

The research farm of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) West and Central Africa Program at Bagauda (Latitude 11°, 40'N, Longitude 08°, 30'E) near Kano, Nigeria, was established in 1988. The first crop of sorghum was planted there in 1990, and was severely attacked by spittle bugs. The two species identified were *Poophilus costalis* (Walker) (Aphrophoridae: Homoptera), which is greyish in colour and *Locris rubens* (Erichson) (Cercopidae: Homoptera) which is reddish-brown (Fig. 1). Surveys (Anon., 1991) revealed that infestation was widespread throughout northern Nigeria, ranging from 22% to 100% of plants in farmers' fields, and was invariably accompanied by yellowish blotches on the leaves. These blotches resembled the yellow leaf blotches that were associated with bacteria, *Pseudomonas* sp. by Zummo (1984). At Bagauda, severe infestation killed young plants and caused the drying of leaves on more mature plants. Apart from brief remarks by Libby (1968) and Murty, Tabo & Ajayi (1994), there are no reports on spittle bugs and their damage potential on sorghum in Nigeria, although earlier studies in Burkina Faso and Côte d'Ivoire (Anon., 1980,1981*a,b*) indicate their potential as sorghum pests in those countries. Studies were, therefore, conducted in 1990–1994 to elucidate aspects of their bionomics and damage potential: distribution, population dynamics, nature of damage, biology, and ecology.

Materials and Methods

Distribution and population dynamics

The population densities of *P. costalis* and *L. rubens* were monitored at Bagauda on various sorghum experiments that had received no insecticide treatment. The experimental design was randomised block design with four replications, and each plot was 7.5 m^2 or 15 m^2. Monitoring was also done in farmers' fields in the Northern and Southern Sudanian agro-ecological zones, and in the northern Guinean and southern Guinean zones of Nigeria. Monitoring involved recording the proportion of plants infested by spittle bugs and the number of spittle bug nymphs and adults on 10 randomly chosen plants per plot at Bagauda, and on 100 plants per farmer's field. The sorghum varieties in these experiments were ICSV 247, ICSV 111, and Samsorg–3. The surveys were conducted in 1990, 1991, 1992, 1993, and 1994 in the months of July to October, when most sorghum were at the vegetative stage. In September and October 1994, similar observations were made at research stations and farmers' fields in Benin and Niger Republics.

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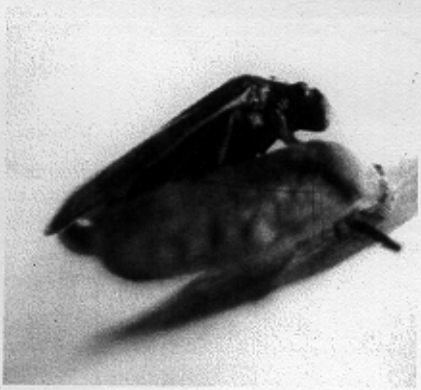

Fig. 1. Adult male and female *Locris rubens* mating while feeding on a sorghum leaf. Bagauda, 1991.

Nature and extent of damage

In 1990, five field-collected *L. rubens* adults were confined per potted 8 wk old sorghum seedling (ICSV 247) in wire-mesh cages (0.8 m × 0.8 m × 1.53 m) to confirm the relationship between spittle bug feeding and yellow leaf blotching on sorghum. After 7 days, the insects were killed with dimethoate at the rate of 0.9 kg a.i. ha^{-1}, and the plants were transferred into larger, insect-free cages (2.9 m × 9.15 m × 2.72 m). Control plants (total of 10 plants) were similarly treated except that no spittle bugs were confined on them. The plants were thereafter examined daily until maturity, 110 days after seedling emergence for differences in the appearance of infested and non-infested plants. Studies focused on *L. rubens*, since it is more abundant than *P. costalis* on sorghum in the major sorghum growing parts of northern Nigeria.

In 1992, field-collected, *L. rubens* adults (0, 2, 5, 10 or 15 pairs per plant) were confined on 8–wk–old sorghum seedlings (ICSV 247) in wire mesh cages (0.8 m × 0.8 m × 1.53 m) for a duration of 2 wk after which they were removed with a spray of dimethoate. In a related trial, 0, 2, 5, 10, or 15 pairs of adult *L. rubens* were similarly caged per plant on 8 wk old seedlings (CV ICSV 247) for a period of 5 wk. In the first trial, the proportion of leaf area affected by leaf blotching was visually estimated for each plant. In both trials, grain yield per plant and grain size were measured at harvest. There were five replications per treatment in each trial.

In 1994, 1, 2, 3 or 5 pairs of adult *L. rubens* were confined per plant for 22 days on 9–wk–old sorghum (CV MR 906) in the field using white muslin cloth cages. Each treatment was replicated four times. The cages were 1.2 m high × 0.5 m wide with an opening at the top and bottom. The bottom end was tied with a piece of string around the stem just above soil level. Insects were introduced via the top end after which it was sealed above the plant. No insects were introduced into the control set of caged plants. At maturity, plant height and grain yield were recorded for all caged plants, and uncaged neighbouring plants.

Biology and ecology

One pair of adult *L. rubens* was confined per plant (total of 20 plants) on 4–wk–old sorghum (CV MR 906) in the field using cages and procedures described above for the 1994 trials. Two caged plants were examined every week for the presence of eggs. Plant tissue, including leaf lamina, midrib, stem, and leaf sheath from the sample plants was examined under a binocular microscope in the laboratory. Substrates containing eggs were placed on moistened soil in a Petri dish and incubated in the laboratory (mean of 28°C and 54% r.h.). Freshly emerged nymphs (total of 124) or freshly collected eggs (total of 100) were introduced into leaf whorls of 4 wk old sorghum seedlings (CV MR 906) in screen cages (0.8 m × 0.8 m × 1.53 m), and monitored until they became adult.

Results and Discussion

Distribution and population dynamics

In each year, infestation by spittle bugs (*P. costalis* and *L. rubens*) was observed on sorghum in farmers' fields and at research stations in all sorghum growing areas of northern Nigeria, including the states of Adamawa, Bauchi, Benue, Borno, Jigawa, Kano, Katsina, Kebbi, Kogi, Kwara, Niger, Plateau, Sokoto, Taraba, and Yobe, as well as the Federal Capital Territory of Abuja. They were also present on sorghum in the southern states of Enugu, Ondo, and Oyo. There is a wide variation in annual rainfall in these states, ranging from 675 mm in the north (e.g. Daura) to 1181 mm in the south (e.g. Lokoja) (Kowal & Knabe, 1972). At Bagauda in Kano state, spittle bugs were hardly noticeable on sorghum in 1988 and 1989, but became important from 1990 onwards. In 1990, *P. costalis* predominated at Bagauda in Kano State, and Samaru in Kaduna State. In 1991, at Bagauda, *P. costalis* occurred from the seedling to the panicle emergence stage, after which *L. rubens* became predominant. *P. costalis* disappeared at grain maturity, but *L. rubens* was present until senescence of the sorghum leaves. They then moved on to an irrigated sorghum plot about 400 m away where their population was so high that chemical control was necessary. Up to 100 nymphs of *P. costalis* per plant were recorded at Samaru in the Northern Guinea savanna. In 1992, *L. rubens* was predominant in the drier parts of Nigeria, while *P. costalis* was scarce. There were, however, more *P. costalis* in the wetter areas (Guinea savanna) than in the drier areas (Sudano - Sahelian Zones). At the Kadawa irrigation project near Bagauda, only *L. rubens* was a problem on off-season sorghum. In 1993, and 1994 *L. rubens* was predominant at Bagauda.

Fig. 2. Yellow leaf blotching symptoms on sorghum leaves fed on by *Locris rubens*. Bagauda, 1992. The insect did not feed on the leaf to the right.

Spittle bugs were also observed in September and October, 1994 causing severe damage, through feeding, on sorghum at research stations and farmers' fields in Benin and Niger Republics. Reports indicate that spittle bugs also are a problem on sorghum in Cameroon (R Kenga, personal communication), Burkina Faso (Anon., 1981*a*), Côte d'Ivoire (Anon., 1980, 1981*b*), and Ghana (P Tanzubil, personal communication).

Libby (1968) described *L. maculata* F. and *P. adustus* Wlk. as pests of sorghum, maize, rice, millet, grasses and sugar cane throughout Nigeria. He also described the nature of damage but made no reference to the yellow leaf blotching observed in this study. Maize is apparently less preferred than sorghum. In 1991, there were 0.3–0.5 *Locris* adults per sorghum plant compared with 0.1 on maize. This confirms the earlier report that *L. rubens* prefers sorghum over maize (Anon., 1980) and pearl millet. The hairy nature of maize and millet leaves probably confers some level of resistance on them relative to sorghum.

The reasons for annual variations in the incidence of spittle bugs and the predominance of one species in 1 yr and not another may be related to rainfall and other environmental factors (Anon., 1980). In this study, the abundance of spittle bugs on sorghum at Bagauda was first noticed in 1990, when total annual rainfall was low (555.8 mm). There was a negative correlation ($r = -0.99$; $y = 192.60 - 0.18x$) between total annual rainfall from 1991 to 1994 (923.6, 913.6, 761.8 and 975.7 mm for 1991, 1992, 1993 and 1994, respectively), and the peak spittle bug populations (25.50, 20.50, 53.50, and 12.88 for 1991, 1992, 1993 and 1994, respectively).

Nature and extent of damage

On caged plants, leaves on which *L. rubens* fed developed yellow blotches (Fig. 2) of various shapes and sizes, but essentially resembled those described by Zummo (1984) for yellow leaf blotch disease. These blotches also resembled those observed on naturally infested plants in the field, confirming that spittle bugs actually caused the symptoms. When severe infestations occurred at the seedling stage, seedlings became progressively yellowish and stunted and eventually died. The symptoms on such plants could easily be confused with a nutrient deficiency,

Table 1. *Effect of artificial infestation with* L. rubens *on sorghum (ICSV 247) at Bagauda, 1992*[a]

No. of spittle bugs per plant (pairs)	Infestation for 2 wk			Infestation for 5 wk		
	% of leaf area with yellow blotching	Grain wt per plant (g)	100 grain wt (g)	Grain wt per plant (g)	Reduction in grain wt compared to non-infested	100 grain wt (g)
0	0	14.9	4.0	6.7	0	2.6
2	20.0	17.3	3.2	6.1	9	2.8
5	33.8	17.5	3.5	4.8	27	2.3
10	84.5	13.0	3.4	4.3	36	3.3
15	85.5	16.7	3.3	4.3	35	3.4
Mean	44.8	15.9	3.5	5.2		2.9
SE	±3.74	±3.94	±0.30	±1.42		±0.44
df	9	9	9	11		11

[a] Adult L. rubens were confined onto 8–wk–old plants for 2 or 5 wk

Table 2. *Effect of* Locris rubens *on plant height and yield parameters in sorghum (ICSV 400) at Bagauda, Nigeria, 1994*[a]

No. of spittle bug adults caged per plant (pairs)	Plant height (cm)	Weight of panicle (g)	Grain yield per panicle (g)
0	169.8 (0)[b]	23.4 (0)	17.5 (0)
1	155.4 (9)	20.4 (13)	16.5 (6)
2	151.0 (11)	19.2 (18)	14.6 (17)
3	140.2 (18)	16.2 (31)	12.8 (27)
5	142.1 (16)	15.2 (35)	11.2 (36)
Mean	151.6	18.9	14.5
SE	±3.96	±4.21	±3.59
df	35	12	12

[a]Adult *L. rubens* collected from the field were caged on 4–wk– old plants for 22 days using muslin cloth cages.

[b]Numbers in parentheses are % reduction for the given parameters.

particularly nitrogen. Severe infestation at the vegetative growth stages adversely affected panicle exertion and caused panicle chaffiness in 1991. The symptoms observed on the leaves resembled those described on maize (Anon., 1975). The association of these symptoms on maize with the feeding activity of spittle bugs (*P. adustus*) was confirmed in the screenhouse (Anon., 1975).

Yellow leaf blotch disease was first observed on sorghum, pearl millet and maize in 1975 and was reported to be induced by *Pseudomonas* sp. (Zummo, 1976, 1984). At IITA, Ibadan, bacteria were associated with these symptoms on maize in only a few cases (Anon., 1975). In a recent study at Samaru, the pathogen was isolated and partially characterised. It was established that the causal agent of this disease is *Xanthomonas* sp. (Akpa, Erinle & Ajayi, 1995). Two isolates, one yellow and the other white, were constantly associated with the diseased tissues. The yellow but not the white type induced hypersensitive reaction in tobacco leaves and produced symptoms of the disease when inoculated onto potted, 6–8 wk old sorghum plants (cultivar ICSV 400).

Thus, it was established that yellow leaf blotch of sorghum is caused by the feeding activity of spittle bugs, as was previously reported by Murty *et al.*, (1994), as well as by bacteria. Further studies were conducted in which isolations from surface sterilised and macerated nymphs of *L. rubens* yielded *Xanthomonas* sp. (Akpa *et al.*, 1995, 1996). This experimental evidence indicated that spittle bugs transmit the bacteria, which are associated with the yellow leaf blotch disease, possibly through their mouthparts while feeding. However, the role of the spittle bug's secretions (saliva and honeydew) in inducing the yellow leaf blotch symptoms still needs to be elucidated.

Fig. 3. Stunting and premature leaf death caused in sorghum (ICSV 400) infested for 22 days by eight pairs of adult *Locris rubens* at Bagauda, Nigeria, 1994.

In 1992, the severity of yellow leaf blotching, i.e. the proportion of the leaf area affected by leaf blotching, caused by *L. rubens* after 2 wk of artificial infestation increased from 20% to 85.5% as the number of caged adults increased from two to 15 pairs per plant (Table 1). When the plants were infested for only 2 wk, there were no discernible effects on grain yield or grain size. However, after 5 wk of infestation, grain yield was reduced by 9% with two pairs, 27% with five pairs, 36% with 10 pairs and 35% with 15 pairs. Spittle bug feeding had no consistent effect on grain size in this trial. Plant growth was adversely affected by prolonged caging, and this explains why plants caged for 5 wk had a lower grain yield and grain size than those caged for only 2 wk.

In 1994, infested plants were shorter and produced smaller panicles and lower grain yields compared with non-infested ones (Table 2). Non-infested plants and those infested with 1 pair of bugs were significantly taller than those infested with 2, 3, or 5 pairs. Although differences for panicle weight and grain yield were not statistically significant, plants with more insects had smaller panicles and yielded less grain than those with fewer insects. For example, non-infested plants were 169.8 cm tall with a panicle weight of 23.4 g and a grain yield of 17.5 g per panicle. One, two, three, and five pairs of adults reduced plant height by 9%, 11%, 18% and 16%, respectively; panicle size by 13, 18%, 31% and 35%, respectively; and grain weight per panicle by 6% 17%, 27% and 36%, respectively.

While non-infested plants were free of symptoms, infested ones had severe yellow leaf blotching and most blotched leaves eventually dried up prematurely (Fig. 3). After the cages and insects were removed, subsequent new leaves were free of blotching and apparently developed normally, thereby indicating that the symptom is not systemic.

Fig. 4. Sorghum leaf sheath with eggs of *Locris rubens* inserted in the epidermis. Bagauda, Nigeria, 1994.

These results show that the extent of damage by spittle bugs depends on the population of spittle bugs, and the duration of infestation. However, in these trials, duration of infestation was confounded by the effect of caging on the plants.

Biology and Ecology

Egg

In 1994, within field cages, eggs of *L. rubens* were laid singly or in batches on the leaf sheath or on the cloth used to cage the adults. One female laid 108 eggs in seven batches ranging from five to 35 eggs per batch. On the leaf sheath, the eggs were inserted in overlapping sequence under the epidermis (Fig. 4). Individual eggs were lanceolate with anterior end being narrower and more pointed than the posterior, which was rounded. Initially, the egg was cream to white in colour with a yellowish spot towards the anterior end. After a few days, the spot turned pinkish while a dark mass appeared at the narrow end. Subsequently, the pink spot became more intense in colour and the dark mass, or, operculum, turned shiny black. At a stage, a cleavage appeared between the operculum and the surrounding egg tissue. This cleavage widened progressively until the first instar nymph emerged from the egg, pushing the operculum ahead of it.

Nymph

The first-instar nymph was yellowish, with a pink abdomen. The eyes were protruding and brown in colour. The antennae, head and legs were whitish. The whole body was transparent, fragile, and the abdominal tip was curved upwards. The head was covered by a layer of bristles. Nymphs placed on severed sorghum leaves on moist filter paper in the laboratory produced the protective foamy substance that is characteristic of spittle bugs. However, they all died within 4 days due to unknown causes. Nymphs transferred into the leaf whorls of caged plants survived and remained within their spittle until adults emerged. Nevertheless, the rate of mortality was extremely high. Of the 124 nymphs transferred, only two developed into adults and both were females. The rest were eaten by ants, drowned by excessive rain water, or, probably died from injuries sustained during their transfer with a camel hair brush. Based on the two female adults reared in captivity, there were five nymphal instars, which lasted a total of 33 days.

Life cycle

In earlier reports (Anon., 1981*a,b*), adults lived for an average of 3.5 days, the second, third, fourth, and fifth instars lasted, respectively for 2, 4, 3.4, and 5.5 days, and mortality was high among the first two nymphal instars; also estimated developmental time from egg to adult was 32 days (Anon., 1980). These earlier reports compare favourably with the findings reported above. However, the death of the adults after only 3.5 days may have been caused by the restriction imposed by their captivity. More detailed work on the biology of the two species of spittle bugs, therefore, needs to be done.

Host plants

Between 1991 and 1994, nymphs and adults of both *P. costalis* and *L. rubens* were observed on the following grass species in Nigeria:

Latin name	Common name
Andropogon gayanus Kunth var *gayanus*	'Gamba grass; Beard grass
Brachiaria spp.	Signal grass; Palissade grass
Commelina spp.	Balasana (Hausa)
Cyperus spp.	Sedge; Nut grass
Dactyloctenium aegyptium (Linn.) P. Beauv.	Comb-fringe grass
Digitaria horizontalis Will.	Wooly finger grass
Eleusine indica Gaertn.	Yard grass
Eragrostis spp.	Buburwa (Hausa)
Mariscus spp.	Sedge
Paspalum spp.	Bastard grass; Ditch millet
Pennisetum spp.	Wild millet
Setaria pallide-fusca (Schum.) Stapf & C E Hubbard	Bristly foxtail grass; Cat's tail grass

Spittle bug hosts identified in earlier studies included sorghum, pearl millet, wild Gramineae, rice, sugar cane, and weeds (Anon., 1980; Libby, 1968).

As rainy season sorghum plants dried up in 1991, *Locris* adults moved onto irrigated sorghum about 400 m away. *Locris* adults were abundant on irrigated sorghum at the Kadawa irrigation scheme in 1992. In December 1994, adult *L. rubens* were encountered feeding on various grasses at the Kadawa irrigation scheme 15 km from Bagauda. This insect therefore spends the dry season on plants in moist environments.

Such plants occur in numerous small and large irrigation projects as well as in the low lying areas (*fadamas*) in the savanna zones. An earlier survey (Anon., 1981*a*) also reported that *L. rubens* and not *P. costalis* was found on irrigated plants in the dry season.

Conclusions

Locris rubens and *Poophilus costalis* are endemic pests of sorghum in Nigeria and neighbouring countries in West and Central Africa. The other hosts include maize, pearl millet and various grasses. The incidence and the relative abundance of the two species vary from year to year, possibly due to changes in environmental factors such as rainfall. *P. costalis* was more abundant on sorghum in the wetter ecological zones while *L. rubens* was predominant in the drier areas. They feed on all parts of the sorghum plant, including the panicles. Their feeding activity causes the yellow leaf blotching symptom that was previously attributed to *Pseudomonas* sp. Severe infestation by spittle bugs can kill seedlings and cause stunting and poor panicle exertion in older plants. Under artificial infestation, yield reduction increased as the number of spittle bugs per plant increased and a yield reduction of 35% was attributed to 15 pairs of adult *L. rubens* caged on sorghum for 5 wk. Spittle bugs are therefore potentially serious economic pests of sorghum, considering that up to 100 nymphs per plant were recorded at Zaria in the Northern Guinea Savanna in 1991. On sorghum, eggs are laid in the leaf sheath and development from egg to adult takes about 33 days in the laboratory. There is a high egg and nymphal mortality and some ants were recorded as predators.

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