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SOROSPORELLA: A CRYPTIC PATHOGEN OF GRASSHOPPERS AND LOCUSTS IN AFRICA

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During surveys for pathogens of orthopteran pests in West Africa, characteristic red, dry, powdery infections of Sahelian grasshoppers were encountered on several pest species occurring in various countries. The causal agent was subsequently identified as belonging to the rarely reported and ill-defined genus *Sorosporella* (Deuteromycotina: Hyphomycetes). Parallel surveys in Madagascar revealed similar disease symptoms on the African migratory locust. This paper describes and discusses the host-pathogen interactions involved.

Insects of the order Orthoptera (locusts and grasshoppers) are major pests of rangeland and arable crops in many arid and semi-arid regions of the world (COPR, 1982). The plague locusts of biblical fame need no introduction in this respect, and in plague years swarms of the desert locust (*Schistocerca gregaria*) can affect crops from West Africa through to Asia. Because of their migratory and cyclical behaviour, locusts have proved to be difficult pests to control, particularly in the mainly subsistence cropping systems found in Africa. Traditionally, control measures here have involved co-ordinated international efforts based on monitoring and forecasting locust populations, followed by aerial spraying with environmentally persistent organochlorines to contain adult swarms and hopper bands. This procedure has become unpopular due to the environmental damage caused, which has led to the widespread banning of such use of these compounds, and also the high cost. For this reason, much of the donor funding has been withdrawn from the early warning programmes; there is thus a need for alternative control strategies. Prior & Greathead (1989) reviewed the potential for biological control, and concluded that fungal pathogens were suitable candidates for investigation. A multi-donor international collaborative research programme for the biological control of locusts and grasshoppers was initiated in 1990, with IIBC taking a key role in the West African surveys (Kooyman & Shah, 1992). Independently funded surveys for fungal pathogens of the African migratory locust (*Locusta migratoria*) were undertaken in Madagascar shortly afterwards. Both surveys revealed the presence of an unusual disease, affecting grasshoppers in West Africa and locusts in Madagascar, each associated with a distinctive fungal genus not previously reported from Africa, nor from these orthopteran hosts.

We describe previously unpublished field observations on the *Sorosporella* outbreaks in West Africa and briefly discuss the current taxonomic status of the genus.

Field observations

During the 1990 rainy season in Mali, surveys for pathogens of orthopteran pests were concentrated in crops and pastures around the village of Mourdiah in Nara District. Dead nymphs of the grasshopper species, *Kraussaria angulifera* (Krauss) (Orthoptera: Acrididae), were first encountered during the beginning of August in a small (approx. 1 hectare) study site. The cadavers were a distinctive brick-red colour and in a fragile, powdery state. Quadrat counts of live and infected nymphs showed that the mean incidence of infection ranged from 1.8 - 5.3%. A total of 206 cadavers were collected from the study site during August and, typically, the dead, red-coloured grasshoppers were found attached to the vegetation (Fig 1), including pearl millet, wild grasses, herbs and shrubs. *K. angulifera* is a relatively large, slow-moving grasshopper species, and an important economic pest particularly of rain-fed cereal crops in West Africa. Massive numbers of this and other grasshopper species occurred in the region during 1985, 1986 and 1989

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(Jago, 1990). Unlike the characteristic 'summit disease' posture adopted by orthopterans infected by *Entomophaga grylli* (Fres.) Batko (see Fig 2), the cadavers of *K. angulifera* killed by 'red muscardine disease' (Steinhaus, 1949), occurred randomly within the vegetation and were typified not only by the red colouration, but also by the occurrence of sticky, dark coloured body fluids exuding from the mouth and anus of the dying insect which served to glue the host to the substrate (Figs 3 & 4). The cadavers assumed a striking brick-red colouration as masses of thick-walled resting bodies or chlamydospores replaced the internal tissues. As the insects were dislodged or fell to the soil, the original adherence sites were identified by the presence of regurgitation marks and strips of red abdominal sclerites on the vegetation. Weathering processes, especially high winds prior to rainstorms, probably erode the cadavers and expose the powdery red spore masses, particularly where the appendages have been dislodged (Fig 5). Spore masses may then be dispersed by wind and/or simply drop to the ground contaminating the soil beneath. The chlamydospores (8 - 10 μm diam) characteristically aggregate in globose to irregular groups or 'spore balls' (40 - 150 μm diam) and these would probably be liberated from the decaying cadaver over a relatively long period of time. Since *K. angulifera* has only one generation per year, and passes the extended dry season (6 - 8 months) as egg pods in the soil, it is probable that the spores would have to 'oversummer' either within the host or in the soil. Almost certainly, transmission to healthy nymphs occurs as they crawl over the soil and vegetation following hatching at the onset of the rains in June or July of the following season.

The development of disease symptoms based on these Mali collections can be summarised thus:

1. Grasshopper moribund, normal green colour replaced by a yellow hue, body fluids released from mouth and anus;
2. Grasshopper dead, abdomen turgid, interior gelatinous, margins of sclerites turn pink, hind legs often raised;
3. Red colour becomes pronounced, particularly on the abdomen;
4. Body becomes dry and uniformly brick-red, abdomen may detach from the thorax, but the alimentary canal remains intact whilst the internal tissues decompose; or, more commonly;
5. Head, legs and abdomen readily detach and the cuticle may break along the pronotal crest and facial sutures, emitting a rich earthy odour.

From observations of dying nymphs collected in the field, the time from stage 1 to 5 is about 4 - 5 days. Following these initial records, the disease was reported from Benin, Chad and Niger on a range of grasshopper species (Shah *et al.*, 1994), although symptomatology varied, such as the absence of excreted body fluids.

The Pathogen

Sorosporella has been used as a genus of convenience for deuteromycete fungi which produce pigmented (typically red) resting spores (chlamydospores) within the host arthropod and which were placed originally in the entomophthoralean genus *Tarichium* Cohn (MacLeod & Müller-Kögler, 1970). Cooke (1892) discussed the 'red endophyte' fungus, *'Tarichia' uvella* Krass., described from coleopteran larvae in Russia and concluded that: 'What it may be is uncertain, but not apparently related to *Empusa*, to which it was at first supposed to be allied. With only such meagre information, this is never likely to be more than one of the mythical names scattered over the pages of botanical literature, representing nothing but an incident of individual experience'. However, this was not to prove an isolated occurrence since a similar fungus had been named previously from cutworm larvae (Lepidoptera), also collected in Russia. The new genus *Sorosporella* Sorokin was proposed to describe the aggregations of resting spores, reflecting the epithet previously coined to denote the grape-like clusters of spores in *T. uvella*.

Later recognition that both fungi possessed conidial states, which were morphologically similar, and therefore that they should be assigned to the Deuteromycotina, has been well documented by Speare (1920). Petch (1942) examined material of a number of *Sorosporella*-like fungi and referred the conidial state to the genus *Syngliocladium* Petch, a genus known only from a specimen collected on a spider host in the UK (Petch, 1932), but apparently lacking the resting spore stage characteristic of *Sorosporella*. A mitosporic (conidial) fungus has never been found on any of the West African orthopteran material. However, when resting spores were cultured on selective media, a conidial state subse-

Fig 1 *Sorosporella* infection of nymph of *Kraussaria angulifera* adhering to vegetation, August 1990, Mali.

Fig 2 *Entomophaga* infection of unknown grasshopper clasping a grass inflorescence in typical 'summit disease' pose, Kenya, Nov. 1989. Since this specimen was found towards the end of the dry season, the fungus was no longer 'active', but the dried sporangiospore masses can still be observed emerging from the abdominal sutures.

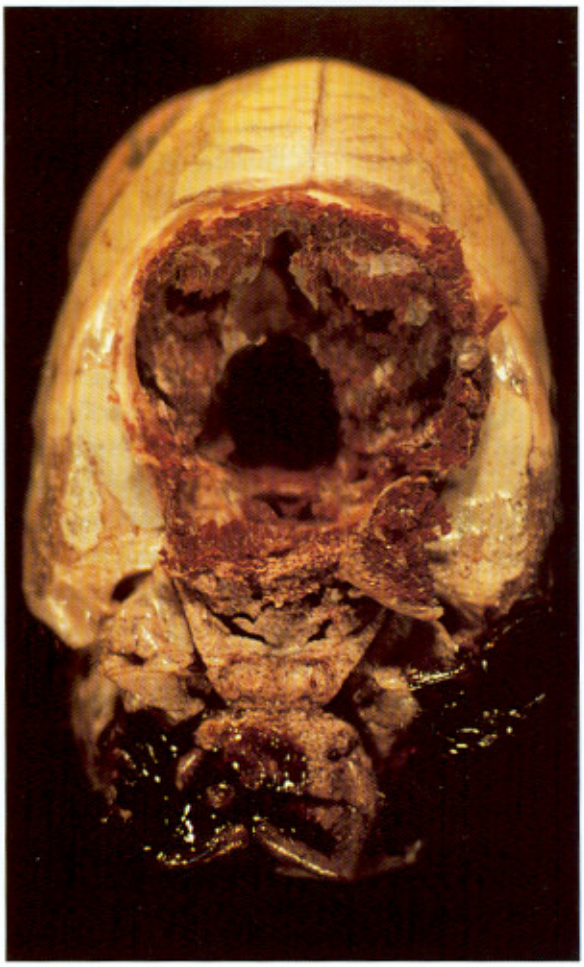

Fig 3 Detached head (rear view) of *Kraussaria angulifera* showing the red, resting spores filling the cranial cavity. Note the sticky, dark-coloured 'vomit' which has congealed around the mouthparts.

quently developed (Shah, 1993). Earlier, Pendland & Boucias (1987) had described a similar mitosporic fungus, which they tentatively assigned to *Syngliocladium*, that developed *in vitro* when *Sorosporella*-like resting spores, derived from mole crickets (Orthoptera: *Gryllotalpidae*) collected in the USA, were incubated. More evidence of a mitosporic stage associated with *Sorosporella* from orthopteran hosts came from Madagascar, during a study of disease outbreaks in the African migratory locust (*Locusta migratoria*) (Welling *et al.*, 1995). Once again, the anamorph was only observed *in vitro*. From the descriptions and illustrations of the recently collected *Sorosporella* isolates from Orthoptera, it is clear that they represent distinct species within a common mitosporic fungal genus. Whether or not these should be referred to *Syngliocladium* is debatable and will await a

more exhaustive study of the genus, and of the type specimen in particular.

Discussion

There seems little doubt that the extensive host colonisation in the form of pigmented, thick-walled resting bodies and the lack of external sporulation on the cadaver suggest a pathogen which is highly adapted to long-term survival in harsh conditions. Both these regions (Sub-Saharan Africa and SW Madagascar) have extended and severe dry seasons. Thus, the slow release of powdery spore aggregations over time, as the host cadaver weathers and degrades, would be an ideal mechanism for both short- and long-distance dispersal, contaminating both soil and vegetation. The appearance of the infective mitosporic stage would await and be stimulated by the onset of the first rains. The early insect instars would probably be infected as they move or migrate over the soil and vegetation, the mucilaginous spores adhering to the insect cuticle.

Rainsplash may also play a role in this dispersal/infection phase. It is also possible that pathogen transmission is facilitated by the scavenging behaviour of grasshoppers described by O'Neill *et al.* (1993). In drought years, it is likely that the spores would need to survive for prolonged periods and there is some evidence that they are highly resistant to desiccation. Resting spores, collected in 1990 then air-dried and conserved in dry conditions for six years were found to germinate and sporulate after a five to ten day lag period on a medium selective for *Verticillium* resting propagules (Christen, 1982) (see Fig 6).

It could be considered surprising that these 'new' orthopteran pathogens, seemingly, have not been discovered or described previously, since they can be responsible for damaging outbreaks on prominent pest insects. However, the absence of external mycelium and sporulation, as well as the friable rather than indurated or mummified state of the cadaver, are not symptomatic of diseases typically caused by entomopathogenic fungi (Samson *et al.*, 1988). It is probable, therefore, that the genus *Sorosporella* has a much more extensive host range and a considerably wider geographical distribution than the literature suggests and belies the statement by Cooke (1892): 'It is to be regretted that such names [*'Sorosporella' uvella*] are not permitted to be forgotten, but as this has been alluded to again so recently it cannot be ignored.'

Fig 4 Congealed fluids around the anal region of *K. angulifera*. Note the resting bodies spilling from the ruptured sclerite.

Fig 5 *K. angulifera* head region, showing the progressive loss of antennae and legs and the spore-filled cavities beneath.

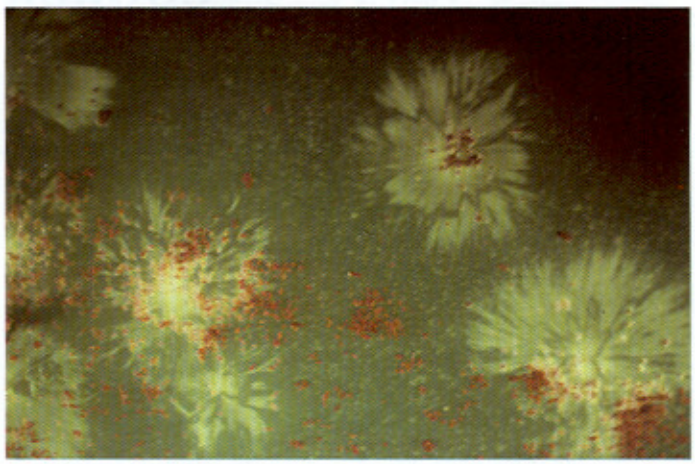

Fig 6 Mitosporic stage of *Sorosporella* growing around 6-year-old resting spore clumps, ex *K. angulifera*, on selective medium.

Acknowledgements

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COOKERY CORNER

AUTUMN BLEWIT MEDLEY

Blewits can be a somewhat oily mushroom and it has been my experience that people either love them or hate them. If you have not found them to your liking, try this recipe and you might be pleasantly surprised.

Ingredients

1lb (500g) Wood Blewits (*Lepista nuda*)

1lb (500g) potatoes.

One sharp apple e.g. Bramley.

1tbsp chopped fresh sage or 1tsp of dried sage.

1/2 pint (500 ml) cheese sauce (See recipe in the May 1997 *Mycologist*)

Salt and pepper for seasoning

A little oil for frying

Method

Slice the Blewits and the onion. Peel, slice and core the apple and sauté together in a little oil until it is cooked through. Add the sage and season well. Meanwhile peel and slice the potatoes and par boil for 2-3 minutes until soft but not falling apart, and then drain.

In a casserole dish put alternating layers of potatoes and Blewit; make sure the top layer ends with potatoes. Cover with the cheese sauce and bake in a moderate oven for 30-40 minutes until the cheese has browned.

This makes a wonderful vegetarian main course or a vegetable dish to accompany most pork menus.

Diana Bateman