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PROSPECTS FOR CONTROLLING ANTHRACNOSE (*COLLETOTRICHUM GLOEOSPORIOIDES*) IN YAMS

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Anthracnose (*Colletotrichum gloeosporioides*) is now the major constraint to the production of water yams (*Dioscorea alata*) worldwide. Field and laboratory experiments were conducted for three consecutive growing seasons in the Caribbean, together with a survey of yam production, to evaluate potential measures for controlling the disease. Chemical and cultural methods of controlling anthracnose on the foliage of yam plants were largely ineffective. In contrast, measures designed to reduce levels of primary inoculum before the growing season (e.g., hot water treatment of planting material) showed promise. Anthracnose-resistant cultivars were identified, although disease symptoms became increasingly severe in consecutive growing seasons, possibly because of changes in the virulence of the pathogen population. Using our results, we discuss the prospects for controlling anthracnose in different yam-based cropping systems in terms of the versatile and ubiquitous nature of the pathogen.

Introduction

Anthracnose is now the major constraint to the production of water yams (*Dioscorea alata*). The causal organism (*Colletotrichum gloeosporioides*) is a fungus that affects the leaves, petioles, and stems of yam plants, resulting in severe necrosis of the foliage. Water yams are cultivated extensively throughout the Caribbean; and as a consequence, the impact of anthracnose has been proportionately greater than in other yam-growing regions. In Guadeloupe, for example, 50%-100% of the fields planted with the preferred cv. Pacala were destroyed by anthracnose; and in Puerto Rico, yield losses of as much as 90% were recorded for the cv. Florido (Degras et al. 1984; Mignucci et al. 1988). But the effects of anthracnose on yam are perhaps most dramatic in Barbados. ‘White Lisbon’, the *D. alata* cultivar that was of particular economic importance to the country, was decimated by the disease during the last decade (Green 1994; Leach 1988). Since 1979, when exports of White Lisbon yams from Barbados exceeded 1 million tons, production has declined by >90% to the point where yams have to be imported to satisfy local demand (BMC 1979, 1991).

In response to increasing disease severity, research to evaluate the potential for controlling anthracnose in yams was conducted over three consecutive growing seasons in Barbados (1990-1992). It comprised field experiments, laboratory studies, and an island-wide survey of yam production. The results of these studies enabled us to evaluate the prospects for controlling anthracnose in the Caribbean and other yam-growing regions.

Experimental Approach

Survey of yam growers

Plantation growers in Barbados were surveyed during April-June 1991. The relatively small area of the island (432 km^2) made a comprehensive survey possible. As cv. White Lisbon was the most severely affected by anthracnose, all 36 plantations that had grown it in the 1990/91 growing season were included in the survey. In addition, 30 smallholders were selected at random from those who had planted $\leq$1 ha of yams. Data were collected by means of interviews conducted personally with growers on their farms. The survey was to establish the range of chemical and cultural practices used to control anthracnose throughout Barbados and to determine the influence of these practices and environmental conditions on disease incidence and severity.

Evaluation of cultural practices for controlling anthracnose

(1) *Planting dates.* A field experiment was undertaken to test the hypothesis that early planting dates could reduce the incidence and severity of anthracnose on *D. alata* cv. White Lisbon. The first planting was in the beginning of May, before the onset of the rainy season. The second and third plantings took place 28 and 56 days later. Disease incidence and severity were assessed weekly throughout the growing season, using the whole plant method as described by Simons and Green (1994a).

(2) *Intercropping.* A field experiment was conducted to determine the effect of intercropping (planting different crops in contiguous rows) on disease incidence and severity. *Dioscorea alata* cv. White Lisbon was intercropped with an anthracnose-resistant cultivar of *D. alata* ('Plimbite') and an anthracnose-resistant species of *Dioscorea* (*D. rotundata* cv. Portuguese), and with tannia (*Xanthosoma sagittifolium*), a non-host crop species. The incidence and severity of anthracnose on the intercrop treatments were compared with the disease levels on *D. alata* cv. White Lisbon in monoculture.

Evaluation of methods for reducing levels of primary inoculum

Previous studies on potential sources of inoculum (soil, crop debris, alternative hosts, and seed setts) highlighted the importance of infected planting material in triggering epidemics of anthracnose. The fungus survives beneath the periderm of up to 20% of the setts sampled (Simons and Green 1994a, 1994b). We tested current methods for reducing the levels of root-borne inocula before the growing season such as dipping setts in benomyl before planting (Small 1988). We also evaluated this measure for eradicating *C. gloeosporioides* from roots that were known to be naturally infected (fungicide treatments for 10 min or 22 h). Another method we tested was the hot water treatment (55 ^{o}C for 10 or 20 min) (Green 1994).

Use of anthracnose-resistant *Dioscorea alata*

Although anthracnose-resistant cultivars are plentiful in the Caribbean, they are not being exploited in Barbados, partly because of reluctance by growers and consumers, and partly because of a lack of relevant research. In 1992, five *D. alata* cultivars that had shown promise on other Caribbean islands were compared with the susceptible cv. White Lisbon for their relative resistance to anthracnose in the field (Table 1). The incidence of anthracnose on reportedly resistant cultivars of *D. alata* cultivated on farms throughout Barbados was also monitored during 1991 to 1993.

Results and Discussion

Use of fungicides for controlling anthracnose

The field survey showed that <10% of smallholders used chemicals to control anthracnose on the foliage of *D. alata* cv. White Lisbon during the growing season, compared with 94% of plantation growers. About half the plantation growers used tractors with boom sprayers rather than knapsack sprayers.

But, irrespective of the mode of chemical application, fungicides usually became ineffective in controlling the disease during the heavy rains. Explanations for the failure of chemical control include infrequent or poorly timed applications (because of costs of chemicals, labour, and machinery), heavy rain washing fungicides off leaf surfaces, and the possible existence of fungicide-resistant strains of *C. gloeosporioides*. Even so, 29% of the plantations could maintain reasonable control until the end of the growing season. These growers began spray programmes before the first symptoms of anthracnose were visible and continued to spray on a weekly basis throughout the growing season, alternating benomyl with chlorothalonil.

Epidemiological studies have subsequently confirmed that high yields (>15 t/ha) can be obtained if this type of spray programme is used to delay the onset of anthracnose until after root bulking (Green 1994; Sweetmore et al. 1994). Where effective and affordable (e.g., on commercial farms and research stations), fungicides can therefore be used as an interim measure for controlling foliar anthracnose, but, in isolation, they are unlikely to provide a sustainable solution.

Evaluation of cultural practices

Earlier planting dates led to a marked delay in the development of anthracnose on *D. alata,* compared with intermediate and later planting dates. This result concurred with previous reports from West Africa (IITA 1982; Nwankiti et al. 1984). The impact of anthracnose on early emerging yams was lower because the plants had had time to establish a canopy before the onset of weather conducive to disease development (continuous rains). Mature leaves of 'White Lisbon' are known to be more resistant to anthracnose than intermediate or juvenile ones (Green 1994; Sweetmore et al. 1994). The beneficial effect of earlier planting was not, however, sufficient for commercial roots to develop, presumably because disease severity was already high at the onset of root bulking. Clearly, for a control measure to be economically effective, it must impede the development of anthracnose until the phase of root bulking is complete.

None of the intercropping treatments had any effect on either the incidence or severity of yam anthracnose or subsequent yields. Failure of the intercrops to reduce the spread of anthracnose on *D. alata* cv. White Lisbon could have occurred for two reasons: The intercrops emerged at about the same time as White Lisbon and were probably ineffective in obstructing the splash dispersal of conidia of *C. gloeosporioides* across ridges. An alternative explanation is that multiple points of primary infection (resulting from root-borne inoculum) were present, facilitating the rapid spread of the disease within the rows of White Lisbon. Despite the apparent failure of intercropping as a control measure for anthracnose in this experiment, results from other studies suggest that the practice warrants further investigation (Mignucci et al. 1988).

In the field experiments, the effect of each cultural practice on the development of anthracnose was considered in isolation. Findings from the survey indicated that also relevant would be to test the efficacy of combining different cropping practices to control anthracnose. Table 2 shows the cropping practices used most commonly on Barbados plantations and smallholdings for cultivating yams. No individual cropping practice or control measure was effective in eliminating the disease during the growing season, but particular combinations of cultural practices and environmental conditions helped reduce disease development on certain farms. Low rainfall (1400 mm/y) and use of healthy planting material, for example, were factors of critical importance in controlling anthracnose. In addition, mixed cultivation, in small areas, of anthracnose-susceptible yams with tolerant cultivars and occasional intercropping with maize may help limit the spread of anthracnose on smallholdings by physically preventing the dispersal of *C. gloeosporioides* and by increasing genetic diversity.

Reducing primary inoculum levels

The incidence of *C. gloeosporioides* in roots treated with fungicide (benomyl) for 10 min was not significantly different from the incidence of the fungus in untreated tubers. A 22-h dip in benomyl reduced *C. gloeosporioides* incidence on roots that were plated out ($P = 0.01$), although isolates of the fungus were still obtained from all samples. The practice of dipping roots in benomyl before planting is now considered as redundant for controlling anthracnose; the fungicide does not eliminate *C. gloeosporioides* perennating beneath the periderm. However, benomyl can still reduce the incidence of other surface-borne pathogens of yam roots.

In contrast to the fungicide treatments, both hot water treatments (55 ^{o}C, 10 or 20 min) eliminated *C. gloeosporioides* from all sample roots. Further studies are being conducted in Nigeria to determine the effect of hot water treatment on germination and its effictiveness for reducing anthracnose incidence and severity during the growing season. Isolates of *C. gloeosporioides* from a wide range of crop and weed species have been found to be also pathogenic on yams (Simons and Green 1994b). The relative importance of these alternative hosts as sources of inoculum must therefore be ascertained before embarking on a large-scale production and distribution of clean planting materials.

Anthracnose-resistant *Dioscorea alata* cultivars

Five cultivars tested in 1992 and compared with *D. alata* cv. White Lisbon showed some resistance to anthracnose, although none was completely symptom free. The cultivars were ranked in order of increasing resistance to anthracnose as follows: White Lisbon, Binugas, Kinabayo/Belep, Oriental, and Plimbite. The first four showed irregular brown lesions that gave rise to extensive foliar necrosis and stem dieback. In contrast, Oriental and Plimbite were showed a characteristically hypersensitive response to infection. By the end of the growing season, maximum disease levels were recorded on all cultivars, except Oriental and Plimbite. Despite the apparent resistance of Plimbite in this experiment, anthracnose was observed to reach epidemic proportions on the cultivar at two plantations monitored in Barbados during the following year. In addition, the local cv. Hunte, considered to be resistant to anthracnose at the beginning of the study (1990), had developed severe disease symptoms by 1992.

Results from the field experiment showed that the response to infection by *C. gloeosporioides* varies considerably according to cultivar. However, resistance may also diminish over a relatively short period, particularly under high inoculum pressure. Similar examples of a rapid "breakdown" in resistance to anthracnose have been reported from other Caribbean countries such as Puerto Rico (Hepperly and Vásquez 1989) and Nigeria (R Asiedu, 1994, personal communication). In such cases, a shift in the virulence pattern of the pathogen population may be facilitated by the presence of many races of *C. gloeosporioides*, together with the potential for rapid multiplication within a growing season, possible through the polycyclic nature of the disease. Clearly, the dynamic nature of host-pathogen interactions should be considered carefully before deciding to promote a new cultivar on a large scale.

Conclusions

Potential methods of controlling anthracnose on yams were evaluated in the Caribbean; results, however, are relevant to developing reliable and effective control strategies for the disease in all yam-growing regions. Chemical and cultural methods of control, applied separately after yam plants have emerged, are frequently insufficient to prevent outbreaks of anthracnose. Strategies for controlling anthracnose on yams should incorporate combinations of such practices, together with methods that can reduce the levels of primary inoculum—particular infected planting material—before the growing season. More importantly, the use of resistant cultivars could provide the basis for the integrated management of anthracnose in all yam-growing regions. New cultivars will need to be developed and used so that they exert minimum selection pressure on the pathogen population.

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Table 1. Characteristics of *Dioscorea alata* yam cultivars evaluated for resistance to anthracnose during the 1992 growing season in Barbados.

Cultivar	Reported response to anthracnose	Source
White Lisbon	Susceptible	Barbados
Oriental	Resistant	Barbados
Belep	Resistant	Guadeloupe
Plimbite	Resistant	Guadeloupe
Kinabayo	Resistant	Puerto Rico
Binugas	Resistant	Puerto Rico

Table 2. Cropping practices most commonly used to cultivate *Dioscorea alata* yams on smallholdings and plantations in Barbados.

Error! Reference source not found. Cropping practice	Smallholdings	%	Plantations	%
Yam rotated with crop	Vegetables	60	Sugar cane	89
Rotation length	≤2 years	60	≥4 years	100
Fertilizer	Pen manure	60	Artificial	75
Intercropping	None	70	None	86
Yam debris	Left on land	100	Left on land	100