EFFICACY OF MAHOGANY BARK AQUEOUS EXTRACTS AND EXPOSURE TO SOLAR HEAT FOR TREATMENT OF POTATO TUBER SOFT ROT CAUSED BY *ERWINIA CAROTOVORA* SSP. *CAROTOVORA*

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Abstract: The efficacy of combining tuber treatment with mahogany bark aqueous extracts and exposure to solar heat for the control of potato tuber soft rot was investigated. Artificially inoculated potato tubers were treated with mahogany bark aqueous extracts and exposed to solar heat for zero, one, two and three hours. The results showed that tuber treatment with the plant extract followed by exposure to solar heat significantly reduced the incidence and severity of tuber soft rot compared to the control group. However, the highest reduction in the incidence and severity of the disease was recorded on tubers treated with the plant extract and incubated immediately after treatment (no exposure to solar heat). This suggests that the plant extract is more effective at lower than higher temperatures. Potato tuber losses due to soft rot could therefore be managed by tuber treatment with mahogany bark extract and no exposure to solar heat.

Key words: potato tuber, soft rot, mahogany bark extracts, solar heat, control

INTRODUCTION

Soft rot of potato tubers is a major threat to potato production worldwide. This is especially true in developing countries where appropriate storage facilities are lacking. In Nigeria there are no defined recommended storage structures. Potato tubers are generally packaged in sacks immediately after harvest for transportation to different parts of the country. This has accounted for about a 40% or more loss of tubers in transit and storage (Bdliya and Dahiru 2006). Cold storage which is commonly used in the developed countries is not feasible in Nigeria. Lack of cold storage in Nigeria is due to acute electricity failure and it is highly uneconomical to run such storage facilities on power generating plants. Previous reports also showed that chemical control even in the developed countries was not very effective in controlling soft rot disease (Harris 1979).

The use of plant products, though effective, has found great usage mostly in insect pest management rather than in control of microorganisms. However, extracts of ginger rhizomes, garlic bulb and aloe vera were successfully use in controlling fungal pathogens (Obagwu *et al*. 1997; Amadioha 1999; Ahmed and Beg 2001). Neem products though extensively used in insect pest management, have also been reported to have some fungicidal (Stoll 1998) and bactericidal properties (Emechebe and Alabi 1997; Bdliya and Dahiru 2006) and have been used in plant disease management. Extracts from mahogany bark and oil from the seeds have been used in the control of *Callosobruchus maculatus* in stored cowpea (Bamaiyi *et al*. 2006) and *Tribolium castaneum* in stored sorghum seeds (Bamaiyi and Bolanta 2006). The limonoids in the mahogany products have also been found effective against cotton leaf worm (Abdelgaleil and Nakatani 2003). Limonoids were also reported to possess some antiviral, antifungal and bactericidal properties (Abdelgaleil *et al*. 2001; Ademola *et al*. 2004).

Air-drying of tubers before storage has provided some level of control and has long been recommended by several authors (Bartz and Kelman 1985 b; Hide and Boorer 1991). Solar heat has been extensively used in the study area to control storage pests. Research in this region has shown that exposure of cowpea and groundnut seeds infested by weevils to solar heat for 2–3 h gave effective control of the weevils (Lale and Ajayi 2001; Lale and Maina 2002; Maina and Lale 2004). However, unlike with insects, only a few reports on the effect of solar heat in controlling bacterial pathogens in the study area have been documented (Bdliya and Haruna 2007). The efficacy of combining solar heat and plant products in managing plant diseases is also an area that has not been exploited.

The high losses of tubers in storage due to soft rot as a result of lack of appropriate storage facilities in the study area still remain a problem and necessitate the search for effective and cheaper methods of controlling the disease. Thus the efficacy of combining tuber treatment with mahogany bark extracts and exposure to so-

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lar heat on the control of tuber soft rot caused by *Erwinia carotovora* ssp. *carotovora* (Ecc) was investigated.

MATERIALS AND METHODS

The experiments were conducted in 2007 and 2008 at the Department of Crop Protection, University of Maiduguri, Nigeria (Sudan savanna) during the three distinct weather periods of the year: April (hot dry period with very high solar heat intensity), August (mid rainy season with high relative humidity and moderate solar heat intensity), and December (cold dry period with low solar heat intensity). These months represent the three weather periods with different solar heat intensities in the study area.

Potato tuber source

Tubers of the potato variety Nicola were used for all the experiments. The fresh mature tubers were obtained from farmers on the Jos Plateau, Nigeria. This is where the bulk of potatoes are produced in Nigeria. Uniformly sized tubers that were healthy in appearance were selected for the experiments. About 4 320 tubers were used during experimental period. The selected tubers were washed under running tap water and stored in the laboratory before the onset of the experiments.

Inoculum preparation

The Ecc used in all the experiments were isolated from potato tubers showing soft rot symptoms. The semi-selective medium for isolation of Ecc as described by Bdliya and Langerfeld (2005 a), was used. The bacteria were preserved on nutrient agar (NA) slants at 4°C till required. Prior to inoculation of tubers, the bacteria were grown on NA plates for 48 h at 27±2°C. The plate cultures were suspended in sterile distilled water and the bacterial concentration adjusted to 10^9cells/ml by measuring the optical density (OD) at 650 nm using Spectrophotometer (Bausch and Lomb Illinois USA).

Preparation of plant extracts

The aqueous extracts of fresh and dried mahogany (*Khaya senegalensis* L.) bark were prepared by pounding 1 kg of fresh or dried bark of the plant and soaking in 4 liters of sterile tap water for 12 hours before filtering through sieve (about 1 mm) into clean plastic containers. The extracts were agitated vigorously before application.

Tuber inoculation

Prior to inoculation, the tubers were surface sterilized in 10% sodium hypochlorite solution for three minutes. The sterilization was followed by rinsing in five changes of sterile tap water. Tubers were allowed to dry at room temperature (about 34±2°C in April, 27±1°C in August and 25±2°C in December). The tubers were artificially inoculated by submergence in the bacterial suspension for thirty minutes. After inoculation, the tubers were allowed to dry at room temperature for thirty minutes before treatment with the mahogany bark extract and exposure to solar heat.

Tuber treatment with plant extracts

The artificially inoculated tubers were sprayed with the plant extract to run-off (approximately at the rate of 100 ml to 100 tubers) using a 6 litre Volpi hand sprayer. The control group consisted of artificially inoculated tubers sprayed with sterile distilled water. All the tubers were allowed to dry for ten minutes before exposure to solar heat or incubation.

Exposure to solar heat

The exposure to solar heat was as described by Bdliya and Haruna (2007). To have a representative effect of the solar heat in the test periods (April, August and December), four experiments on a weekly basis were set out for each of the three months. Also to get full exposure to solar heat, the treated tubers were spread out on a concrete platform in an open area outside the laboratory. Prior to the onset of the experiments, the platform was washed with 10% sodium hypochlorite solution and rinsed with sterile tap water and allowed to dry. The tubers were exposed to solar heat between 12.00 noon and 3.00 pm local time when the sun was at its hottest peak. Immediately after exposure to solar heat, the inoculated tubers were sprayed with the mahogany bark extracts, the tubers were spread out on the surface sterilized platform. The actual solar heat reaching the tuber surfaces was measured by placing a thermometer on the surface of the spread tubers while the relative humidity at the exposure time was measured using a whirling thermohydrograph.

For uniformity, all the tubers were spread out on the platform at the same time. Four replicate samples of fifty tubers were taken at the end of each exposure time of zero, one, two and three hours and brought into the laboratory for incubation. Zero hour exposure meant no exposure to solar heat, i.e. immediately after spraying with the extract. The temperature and relative humidity at the beginning and end of each exposure time was recorded. The means of the four experiments in the month, were computed to get the mean solar heat for the period of the experiment.

Experimental set up

After the inoculated tubers were exposed to solar heat as described above, fifty tuber samples, replicated four times were taken at the end of each exposure time and placed in surface sterilized plastic containers (about 40x40x10 cm). The containers with lids were arranged on shelves in an incubator in the laboratory. Moist tissue paper was placed at the bottom of each container to maintain high humidity within the container. Containers holding the control tubers were arranged side by side with the exposed tubers in a completely randomized design. The tubers were then incubated for three days at 27±2°C in the incubator. Evaluation was based on the incidence and severity of tuber soft rot. The tuber soft rot severity was assessed on a scale of 0–5 as described by Bdliya and Langerfeld (2005b),

where:
0 – no symptom of root
1 – 1–15% of tuber rotten
2 – 16–30% of tuber rotten
3 – 31–45% of tuber rotten
4 – 46–60% of tuber rotten
5 ≥ 61% of tuber rotten.

The severity was then computed using the formula:

$$S = \frac{\sum n}{N \times 5} \times 100$$

where:
S – severity of tuber rot (%)
∑n – sum of individual ratings
N – total number of potato tubers assessed
5 – highest score on the severity scale.

Data analysis

Data obtained were subjected to analysis of variance. The difference in mean was compared using either least significant difference (LSD) or plotting standard error of means at 5% level of probability as described by Gomez and Gomez (1984).

RESULTS

The results of the experiments conducted during the hot period (April) showed that the mean temperature measured on the tuber surfaces at the time of exposure to solar heat was 47.6°C. The mean room temperature was 32.4°C. The mean relative humidity was 16.3%. Disease incidence was generally lower on tubers treated with either fresh or dried mahogany bark extracts and exposed to solar heat or incubated immediately compared to the control group (Fig. 1). The lowest incidence of the disease was recorded in tubers treated with extracts from dried mahogany bark and exposed for 0 hour to solar heat (incubated immediately). The incidence of the disease on the control group decreased with increased exposure time to solar heat, however, the disease incidence results were still higher than that of the tubers treated with the plant extract before exposure to solar heat. The disease severity followed a similar trend to that of the disease incidence with the lower severity recorded on tubers treated with the plant extracts and exposure to solar heat or incubated immediately. The lowest disease severity was also recorded on tubers treated with the plant extracts and incubated immediately; not exposed to solar heat.

During the rainy season (August) the mean temperature on exposed tuber surfaces outside the laboratory was 39.2°C, while the mean room temperature was 29°C. The mean relative humidity was 85.4%. The incidence and severity of the disease were also significantly lower on tubers treated with either fresh or dried mahogany bark extracts compared to the control group. Also tubers treated with the plant extracts and exposed for 0 hour had significantly lower disease incidence and severity than those exposed for three hours to solar heat (Fig. 2). The lowest

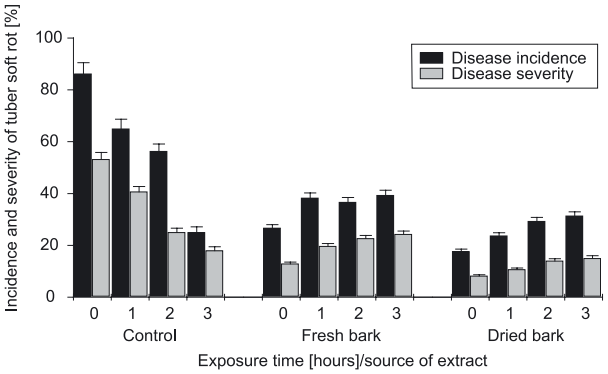

Fig. 1. Effect of mahogany bark aqueous extracts and exposure to solar heat on the control of potato tuber soft rot during the hot dry period (April; exposure temperature = 47.6°C; RH = 16.3%). 0, 1, 2 and 3 hours – exposure time to solar heat. Data are the mean for two years. Bars indicate standard error of means at 5% probability level

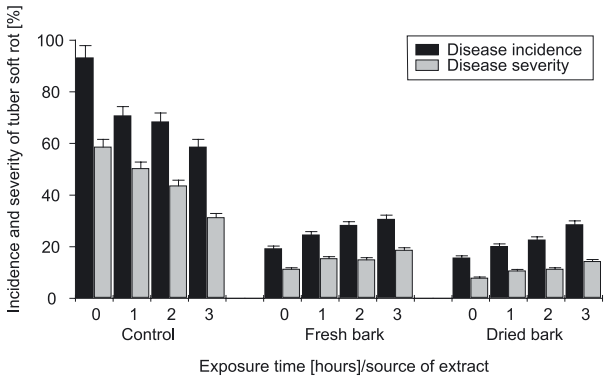

Fig. 2. Effect of mahogany bark aqueous extracts and exposure to solar heat on the control of potato tuber soft rot during the humid rainy season (August; exposure temperature = 39.2°C; RH = 85.4%). 0, 1, 2 and 3 hours – exposure time to solar heat. Data are the mean for two years. Bars indicate standard error of means at 5% probability level

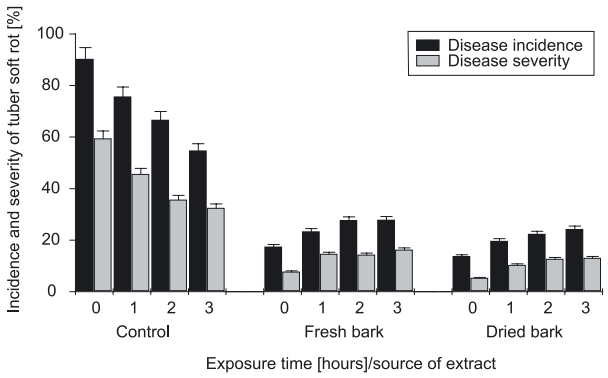

Fig. 3. Effect of mahogany bark aqueous extracts and exposure to solar heat on the control of potato tuber soft rot during the cold dry period (December; exposure temperature = 29.2°C; RH = 19.6%). 0, 1, 2 and 3 hours – exposure time to solar heat. Data are the mean for two years. Bars indicate standard error of means at 5% probability level

incidence and severity of the disease was also recorded on the tubers treated with dried bark extracts not exposed to solar heat.

Figure 3 show the effect of the mahogany bark extract and exposure to solar heat on the incidence and severity

of potato tuber soft rot, during the colder period (December) of the year. The mean temperature on the surface of exposed tubers during this period was 29.2°C, while the mean room temperature was 24.3°C. The mean relative humidity was 19.6%. The incidence and severity of tuber soft rot was also significantly lower on tubers treated with either fresh or dried bark extracts with or without exposure to solar heat compared to the control group. The lowest disease incidence and severity was also recorded on tubers treated with dried bark extracts and exposed for 0 hours.

Exposure to solar heat alone significantly reduced the incidence and severity of the disease (control group). Disease, reduction, though, was not as marked as on the tubers treated with the plant extract before exposure to solar heat. Generally, the combination of solar heat and mahogany bark extracts reduced the incidence and severity of tuber soft rot compared to the control group in all the experiments.

DISCUSSION

The results of this study have shown that tuber treatment with mahogany bark extract can be used for controlling potato tuber soft rot disease. Several authors have also reported the effectiveness of plant products in the management of both insect pests and diseases (Amadioha 1999; Ahmed and Beg 2001; Abdelgaleil and Nakatani 2003; Abdelgaleil *et al*. 2004; Bdliya and Dahiru 2006; Bamaiyi *et al*. 2006). Similarly, the effect of solar heat in controlling potato tuber soft rot has been reported by some authors (Bdliya and Haruna 2007). In this study integrating tuber treatment with mahogany bark extract and exposure to solar heat significantly reduced the incidence and severity of tuber soft rot compared to the control group. However, long exposures of the extract treated tubers to solar heat tend to slightly increase the incidence and severity of tuber soft rot compared to those incubated immediately (not exposed to solar heat). Probably, long exposures to solar heat affect the potency of the mahogany bark extract or facilitate the quick drying out of the extract on the tuber surfaces, reducing its effectiveness. This might explain why the incidence and severity of the disease was significantly lower at 0 hour exposures for both the fresh and dried bark extracts than after three hours of exposure time. Also the extract from the dried bark was more effective than that from the fresh bark. Probably the active compounds are more concentrated in the dried bark than in the fresh bark which contains a higher water content at the time of the extract preparation. The soaking of the fresh bark in water might have further diluted the concentration of the active substance compared to the soaking of the powder from the dried bark.

Although, there are few reports on the use of mahogany products in controlling plant pathogens, extracts from the plant have been extensively used in the control of insect pests of crops, particularly cotton boll worm (Abdelgaleil *et al*. 2004). A part from the insecticidal properties of mahogany products, these products have also been reported to possess antifungal and bactericidal properties (Abdelgaleil *et al*. 2001; Ademola *et al*. 2004). These properties correspond well to mahogany's effectiveness in controlling the soft rot bacteria on the treated tubers in this study. The effectiveness of other plant products in controlling plant pathogens have been reported by other authors. Bdliya and Dahiru (2006) reported that aqueous extracts of neem (*Azadirachta indica* L.) leaf and seeds were more effective in controlling bacterial soft rot of potato tubers than leaf extracts of Siamese cassia (*Senna siamea*) and ironweed (*Vernonia galamensis*). Garlic and neem products have also been found to contain some antimicrobial properties and have been used in the control of fungal and bacterial pathogens (Obagwu *et al*. 1997). In our study, the fresh and dried mahogany bark extracts have also shown strong antimicrobial properties. Mahogany bark extracts significantly reduced the incidence and severity of tuber soft rot compared to the control group.

The effectiveness of solar heat in controlling tuber soft rot could be seen clearly in the control group where exposure for three hours significantly reduced the incidence and severity of the disease compared to 0 hour exposures. The effectiveness of solar heat in controlling potato tuber soft rot had been reported earlier (Bdliya and Haruna 2007). Similarly, Adams and Griffith (1978) and Hide and Boorer (1991) have also reported that air drying of tubers before storage, reduces the incidence and severity of tuber soft rot during storage. Although solar heat alone was found to reduce the incidence and severity of tuber soft rot (Bdliya and Haruna 2007), the combined effect of the mahogany bark extract and solar heat was more effective in controlling the disease than the single effect of the solar heat as shown in this study. However, the results have also shown that mahogany bark extract treatments with no solar heat exposure produce the best results. Thus, it could also be used alone as a treatment for the control of tuber soft rot.

Solar heat has been successfully used in the control of soft rot erwinias (Bdliya and Haruna 2007). The abundance of solar heat at the required intensity to control the disease, however, is not always available throughout the year. Hence the need for the combination of solar heat with other methods to adequately control the disease during those periods when the solar heat intensity is low. The results of this study demonstrated that tuber treatment with mahogany bark extract and exposure to even low solar heat, significantly reduced the incidence and severity of potato tuber soft rot. This treatment could be used even during periods when the solar heat is low. The highest control of the disease was recorded on tubers treated with the mahogany extract and not exposed to solar heat. Such control further demonstrates the effectiveness of mahogany extract in controlling the disease even without exposure to solar heat. Thus during the cooler periods of the year (during harmattan and the rainy season) when temperatures are generally low, tuber treatment with mahogany bark extract before storage may help to reduce effect of soft rot erwinias. Spraying the tubers with the extract provided adequate coverage of the tubers, with reduced volume of extract and could be easily adopted by farmers. Nevertheless, more research is needed to determine the degree of penetration of the ex-

tract into the lenticels so as to ascertain the efficacy of the extracts in controlling latent infection. The major mode of tuber contamination by the soft rot erwinias is indeed latent infection.

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POLISH SUMMARY

SKUTECZNOŚĆ WODNYCH WYCIĄGÓW Z KORY MACHONII I EKSPONOWANIE NA ŚWIATŁO SŁONECZNE W TRAKTOWANIU PRZECIWKO MIĘKKIEJ ZGNILIŹNIE BULW ZIEMNIAKA WYWOŁANEJ PRZEZ *ERWINIA CAROTOVORA* SPP. *CAROTOVORA*

Badano skuteczność połączenia traktowania bulw wodnymi wyciągami z kory machonii oraz ekspozycji na ciepło słoneczne w zwalczaniu miękkiej zgnilizny bulw. Sztucznie zakażane bulwy ziemniaka traktowano ciepłem słonecznym przez zero, jedną, dwie i trzy godziny. Uzyskane wyniki wykazały, że traktowanie bulw wyciągiem roślinnym, a następnie ekspozycja na ciepło słoneczne istotnie zmniejszały występowanie i nasilenie miękkiej zgnilizny bulw w porównaniu do kontroli. Najwyższą redukcję występowania i nasilenia choroby odnotowano na bulwach traktowanych wyciągiem z roślin i inkubowanych natychmiast po potraktowaniu (bez ekspozycji na ciepło słoneczne). Badania sugerują, że wyciąg roślinny jest skuteczniejszy w niższych temperaturach. Straty bulw spowodowane miękką zgnilizną mogą być kontrolowane przez ich traktowanie wyciągiem z kory, bez ekspozycji na ciepło słoneczne.