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AFRICAN WALNUT (*Tetracarpidium conophorum*) DISEASES RESEARCH IN NIGERIA: CURRENT STATUS AND THE WAY FORWARD

Obani, F.T.; Nwaogu, A. G. and Onyebuchi, E.
Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria
Corresponding author: tochyfloxy@gmail.com

SUMMARY

African walnut (*Tetracarpidium conophorum*- Mull. Arg) is a cash and economic crop widely grown for its edible seed nuts rich in protein, oils including omega-3 fatty acids, vitamins and minerals with excellent flavor and rich source of energy. A good percentage of the nuts and their nutritional composition are lost to postharvest fungi deterioration. Hence, the effective and adequate production of any crop takes into consideration disease management which is necessary to avoid losing both quality and quantity of crop produce. Infection of crops both in the field and post-harvest levels negatively affect the economic potentials of the crop. There are reports of diseases affecting African walnut in many African countries and many other countries of the world. But information on African walnut diseases in Nigeria are grossly lacking. African walnut has not received the desired research attention especially in the area of disease management; therefore, the aim of this review is to update and discuss the available information on walnut diseases if any in Nigeria. The current status of walnut diseases research and the recommended disease control strategies of African walnut are also discussed.

Key words: African walnut, Nigeria, diseases research, economic potentials

Nuts have remained a major part of the diet for humans since pre-agricultural times (50). Some of the world recognized and popular edible nuts include almonds, cashew nuts, peanuts, hazel nuts, macadamias, pecans, pistachios, Brazil nuts and English walnut (36;14).

Among all nuts, Walnut fruit (*Tetracarpidium conophorum*- Mull. Arg) is rich in protein, oils including omega-3 fatty acids, vitamins and minerals with excellent flavor and rich source of energy. They are edible seeds that are widely cultivated for their delicacy.

The African Walnut is an incredible plant that originated from tropical West African nations of Sierra Leone, to Angola, Nigeria and different nations in West Africa (59).

The plant is popularly known as African walnut, black walnut and Nigerian walnut (28). Prominent species include *Juglans regia* (L.), known as the English walnut and belonging to the family Juglandaceae (17). The tropical African walnut known as *Tetracarpidium conophorum* (62), belongs to the family Euphorbiaceae (27), though Adebona *et al.,* (2) stated that some walnut species are found in the family Olacaceae.

In Nigeria, among the Yoruba tribe, the walnut is known as awusa orasala,in Igbo as ukpa, or oke okpokirinya and gawudi bairi in Hausa; Ekporo by Efik and Ibibios of Cross River and Akwa Ibom states, Okwe in Edo and Gwandi, Bairi in Hausa (4). and it is known as okhue or okwe among the Bini tribe of Edo State (4;19;48). In Sierra Leone, it is called musyabassa and in western Cameroon, it is known as kaso,

among other local names (17).

Walnut is grown in 54 countries of the world. In 2017, the largest walnut producing countries were China, USA, Iran, Turkey, Mexico, Ukraine and Chile, whereas Uzbekistan stood eighth, and third in the world on fruit productivity per hectare (31). The African Walnut is generally produced in the western and eastern parts of Nigeria and is additionally indigenous to Cameroon, Central African Republic, Congo, Gabon and Niger (41).

In Nigeria, it is found in Southern states, Akwa Ibom, Cross River, Lagos, Akure, Kogi, Ajaawa, Ogbomosho, Ibadan, Osun, Ekiti and Ondo (60;59). It is largely available in all cocoa-producing states in Nigeria and in the southern part of Nigeria (77).

The seeds are consumed as snacks and refreshments. It is a perennial cash crop and an economic climbing hard wood plant that is widely grown for its edible seed nut (29;27;19).

The walnut is generally referred to as the conophor tree or conophor nut (41). It is a perennial cash and economic crop that is widely grown for its edible seed nut (29;27;20).

In Nigeria, the walnuts are basically processed by boiling in water or roasting in hot sand before consumption as snacks (58). The flour is used as a soup thickener in some parts of Nigeria. In ethnobotanical medicine, the nuts and leaves are extensively used in decoctions for treatment of several ailments such as malaria, male sterility dysfunctions, dysentery, constipation, abdominal cramps and general fever, as well as in management of chronic diseases such as diabetes, cancer and high blood pressure (6;3).

However, lack of storage facilities has hampered the market value of the walnut (47) and the nuts must be consumed within 1–2 days when cooked or else they will become sour, foul-smelling and unpleasant for sale and consumption (48).

The effective and adequate production of any crop takes into consideration disease management which is necessary to avoid losing both quality and quantity of crop produce. Infection of crops both in the field and post-harvest levels negatively affect the economic potentials of the crop. However. walnut as a crop is neglected in terms of research and particularly, the disease management aspect. There are reports of diseases affecting African walnut in many African countries and many other countries of the world, which is grossly lacking in Nigeria. Several literatures reviewed reveal that no tangible research has been done on diseases affecting walnut in Nigeria. Conscious research efforts directed on walnut in different areas of crop protection is very crucial. The need to conduct such studies in different parts of Nigeria where walnut is grown to generate and make available substantive scientific reports on the extent of diseases. This will help to determine the management efforts that could be carried out to ensure increased productivity and quality of walnuts in Nigeria. Generally, African walnut has not received the desired research attention especially in the area of disease management. Therefore, the aim of this review is to update and discuss the available information on walnut diseases if any in Nigeria, also to illuminate the current status of walnut diseases research and the recommended possible disease control strategies of African walnut.

Source: Ayoola *et al.*, 2011

Figure 1. (a) *Tetracarpidium conophorum* in its natural habitat (b) Seed nuts

2.0 Report of Previous Research Works on Major Diseases ofWalnut and their Management

2.1 Walnut Blight: Walnut blight or bacterial blight caused by the bacterial pathogen *Xanthomonas arboricola pv. juglandis* (Xaj), attacks flowers, shoots, leaves, buds and fruits (55). Early infection causes nut drop while late infection results in nut shriveling and discolouration while fruit infections can cause great economic loss, and can lead to almost all walnut fruits drop prematurely in some Australian orchards (52).

The disease has been reported in Europe, Asia, Africa, the Western Hemisphere and Oceania (30). In Australia, symptoms resembling those of walnut blight have been reported on fruits and leaves of introduced trees in New South Wales, South Australia, Tasmania, Victoria and Western Australia (66;22;61;7;1;37). Xaj was confirmed as the cause of walnut blight in Tasmania recently (51).

The current management strategy for walnut blight in Australia is to protect susceptible fruits by application of copper-based biocides at weekly intervals from bud-burst for 4-5 weeks, and then at 7–14-day intervals depending on the weather, for up to ten applications per year (52). Copper resistant strains of Xaj were first identified in walnut orchards in France and Northern California (USA) (34;53) and copper tolerant strains of Xaj have been identified in Australian orchards (69).

With the emergence of copper tolerant strains of bacterium from France (34), use of iron amended (50 µµg/ml) copper containing bactericides (Kocide 101 or Champion) is advised for copper tolerant and sensitive strains (53;42). The current research in Australia is aimed at understanding how walnut blight epidemics progress in time so that copper-based sprays can be timed in relation to pathogen activity and likely impact on crop yield and quality (51).

2.2 Crown Gall: The disease has been known since 1853 and is almost worldwide in distribution, reported on walnut from India by Jindal and Dwivedi (42). Crown gall on walnuts is caused by two species of bacteria: *Agrobacterium tumefaciens* and *A. rhizogenes* (81). In California, *A. tumefaciens* is a more common causal agent

of crown gall in than *A. rhizogenes,* although the reverse may be true in Oregon or other locales (57). Interactions between *A. tumefaciens* and various host plants have been investigated extensively on a molecular level. However, scientists know less about the impact of the disease and how the pathogen survives and spreads in nature. In 1912, Smith *et al.* stated that crown galls are "injurious to the plant in varying degrees, depending on the species, on the parts attacked, on the size and vigor of the individual, etc. They are most injurious to young and rapidly growing plants." According to the literature, the impact of crown gall on fruit and nut trees varies. For example, Garrett (35) reported that crown gall had no consistent impact on the growth of cherry trees, while others have reported that the disease causes stunting of pecans (15) and peaches (40), and mortality of peaches and cherries (45).

Crown gall affects nut and fruit trees in both nurseries and orchards. Based on observations of stone fruit trees, Moore and Canfield (57) and Alconero (5) suggested that some infections are "latent," occurring in the nursery, but only developing galls after transplantation. Using more modern technology of DNA sequencing, Pionnat *et al*. (64) concluded that pathogenic *A. tumefaciens* was transmitted on asymptomatic rootstocks of roses, and that the transmitted pathogen then caused disease in some buyers' fields.

2.3 Leaf Blotch and Anthracnose: Anthracnose is the wide spread foliar disease of walnut and the fungus attacks leaves, nuts and shoots of the current season growth (12). Zamani *et al.,* (82) observed that the walnut anthracnose was caused by *Marssonina juglandis* (Lib.). Symptoms develop on the leaves and fruits as irregular necrotic areas that are often surrounded by small chlorotic halos. The disease causes premature defoliation, slows down plant growth, reduces quantity and quality of nut crops, thereby resulting in huge economic loss in the walnut cultivation regions of the world (11;78;46). The disease is wide spread in occurrence and destructive at young nut stage causing premature nut drop and extensive yield loss. It was observed in almost all the walnut growing localities of Kashmir (49).

Walnut anthracnose or black spot/blotch has been reportedly considered as most serious fungal disease of African walnut and throughout the walnut growing regions including North and South America, Europe, Iran and other Asian countries where it has been reported (8;13;12;67). In India, Kaul (49) reported the occurrence of walnut anthracnose disease for the first time from Kashmir valley. Hassan (38) reported the occurrence of walnut anthracnose in Iraq while as, Werner (79) reported from Poland. It is indigenous to North America (76), economically important in the main production areas of Italy and Hungary (9;63) and most widespread and dangerous disease in Bulgaria (46).

Saremi and Amiri (70) reported that this disease caused 60-80% yield losses in quality and quantity in Iran. Walnut anthracnose results in reduction in quantitative parameters such as size, mass and actual crop of nuts, failure in metabolic processes in leaves and change in biochemical indices with reduction in nut yield which varied from cultivar to cultivar (63;46). Early infection on nuts results in premature fruit drop (80).

2.4 Downy leaf spot: This disease has been easily recognized by its very distinctive symptoms, namely snowy-white, powdery growth confined by leaf veins on the undersurface of leaves, and yellow or light green spots on upper surface opposite to white growth, caused by a fungus

Microstroma juglandis (Berenger) Sacc (33;44). Except the Persian walnut, *M. juglandis* infects more than 6 species of the *Juglans* genus (39). In Uzbekistan and neighbor countries more than 10 species of *Juglans*genus were reported as parasites of walnut trees (54). It causes destruction of walnut trees' wood (heart rot), produces cavities on stems, decreases life time and yields of trees (65).

In June 2011, walnuts from orchards in Kimcheon and Muan, in southern Korea, were found to exhibit downy mildew-like symptoms of a foliar disease. Based on morphological and cultural characteristics, the causal fungus was identified as *Microstroma juglandis* obtained from GenBank databases, thus confirming its identity. Pathogenicity tests were conducted on leaves of walnut seedlings, fulfilling Koch's postulates. The disease has been previously reported in North America, Europe, Oceania and some western Asia. This is the first report of downy leaf spot on walnuts in East Asia (68).

2.5 Root and Crown Rot: Crown and root rots caused by species of *Phytophthora* are among the most serious diseases of walnut worldwide. In California, more than 10 species of *Phytophthora* have been implicated in the diseases, but *P. cinnamomi* and *P. citricola* were determined to be the most virulent (56). There has been continued interest in comprehensive evaluation of Paradox hybrids for resistance to *Phytophthora spp.* and other desirable traits. Paradox is more resistant than Northern California (NCa) black or English seedling rootstocks to most *Phytophthora spp.*

2.6 Shoestring Root and Crown Rot: The disease is caused by fungus *Armillaria mella* (Varhl. Ex Fr.) Kumm., the fruiting bodies of which appear at the base of infected trees in October and November. The causal fungus may be brought into the orchard on infected nursery stocks or it may be present in the soil. The most reliable diagnosis can be done by its mycelium strands resembling flattened shoestring. The leaves of infected trees turn yellowish and sometimes fall prematurely. Wounds at the trunk or the main roots increase the chance of infection, application of fumigants like carbon disulfide by making holes 20 to 25 cm deep at a distance of 45cm apart is recommended and use of resistant rootstocks such as Eastern Black Walnut and Hinds Black California Walnut are recommended (21).

2**.7 Thousand cankers**: Thousand cankers is a newly recognized disease of walnuts, caused by a fungus (*Geosmithia morbida*) that is spread by the walnut twig beetle (*Pityophthorus juglandis*). The beetle is endemic to the native range of Arizona walnut (Arizona, New Mexico, and Chihuahua, Mexico), and was first identified in Utah in 1988. Widespread mortality of walnuts in the early 2000s in Colorado and Utah led to the discovery of the pathogen-vector complex. The name of the disease comes from the numerous necrotic lesions found on the cambium of infected trees (75). The fungus kills black walnut trees often within 3 years of the development of the first symptoms (25). It may take several years of fungal attack before symptoms are visible, starting with yellowing leaves and thinning tree crown. As the disease progresses, foliage wilts, larger branches die, and eventually the tree dies (75).

2**.8 Stem Cankers and Dieback Diseases:** Caused by *Fusarium solani*. Bark of walnut tree dries up and splits, cracks also develop in the underneath wood which leads to the drying of foliage and twigs, resulting in defoliation. As the disease progresses fruiting bodies of causal fungi develop.

There are several canker diseases causing pathogens:

a. *Cytospora sp.* Different species of *Cytospora* have been found to cause canker in different nut crops. In India, C. juglandis has been reported to infect 6 to 9 years seedlings of walnut (Putto and Chaudhary, 1984). In addition,*C. juglandicola*, *C. leucostoma* and *C. cincta* have also been reported.

b. *Fusarium solani:* The fungus has been reported to cause canker on black walnut (*J. nigra*) in North America and more than 84 per cent plantation exhibited stem cankers (18).

c. *Botryosphaeria sp.* Two species of the fungus namely (*B. dothidea* (Moug. Ex Fr.) Ces. and de Not. And *B. Ribis* Gross and Duggar) have been reported to cause stem canker and dieback of walnut (53; 32).

2.9 Cherry Walnut blackline (leaf roll virus): Cherry leaf roll virus (CLRV) is associated to different symptoms on different hosts, propagated on seedlings of Northern California black walnut (*Juglans hindsii*), natural hybrid Paradox (*J. hindsii x J. regia*), Chinese wingnut (*Pteriocarya stenoptera*) and several species of Juglans, this virus causes a disease called Walnut blackline (71). It is transmitted by mechanical inoculation, grafting, pollen and nematodes (16). The key symptom of walnut blackline disease is a gradual girdling by a narrow, black, necrotic strip of cambium and phloem tissues at the rootstock-scion union, resulting in decline and death of the English walnut scion. On English walnut propagated on paradox rootstock, the disease develops an extensive necrosis of bark in the rootstock that is delineated by the scion at the graft union (56).

2.11 Walnut ringspot: The properties of a virus causing walnut ringspot which had been identified by the visual examination of symptoms on leaves and fruits of walnut trees in Slovakia were studied where purified virus was used for antiserum production. The virus was transmitted mechanically to *Chenopodium quinoa* Willd., *Chenopodium amaranticolor* Coste et Reyn., *Nicotiana clevelandii* Gray, *Phaseolus vulgaris* L. cv. Bountiful. In Great Britain, Cooper (23;24) isolated a virus identified as CLRV. Delbos *et al.* (26) described the CLRV virus of attacked Juglans nigra trees in France. In the USA, Mircetich *et al.* (56) isolated CLRV and described the walnut ringspot in Hungary.

3.0 Research Status of walnut diseases in Nigeria:

In spite of the promising potentials of the African walnut in the field of nutrition and medicine, there is almost no reports that have been documented as regards research on diseases affecting walnut in Nigeria.

In Nigeria, as one of the many developing nations, there is a continuous search for alternatives to animal protein which is fast getting out of reach for many citizens as a result of poor governance, inflation, political turbulence, ethnic and guerrilla wars and biting economic hardship. Great attention is being turned to plant protein sources of which nuts are of paramount interest. Several nuts exist in the wild in African forests and many are yet to be documented. Some that have been brought to the lime light are yet to be thoroughly researched about in Nigeria. Many of these nuts are consumed daily either raw or processed.

High temperatures and relative humidity which may be detrimental to food quality and may trigger fungal growth or even maillard reactions leads to rancidity. Walnut pod is very susceptible to fungal infestation and grows mouldy within few days of harvesting as the pods decay to release the nuts. Although the nuts may be processed,

the fungal contamination is noticed when the shells are cracked as the cotyledons become slimy, discoloured or even rotted in severe cases. This affects the sale by retailers and quality of walnuts in terms of nutritional value and general acceptance by the buyers.

Despite concerns over mycotoxin contamination in fungi contaminated nuts, there is a scarcity of research on potential contamination of these nuts and how risks can be accentuated by postharvest handling and there is need to study the different diseases that may be affecting the growth of walnut as well as its storability and quality after harvesting.

4.0 The Way Forward for Walnut Diseases Research in Nigeria

4.1 Disease diagnosis

Reports and information on African walnut diseases research in Nigeria are grossly lacking. A greater percentage of walnut grown in Nigeria are grown in the wild. This does not in any way imply that walnut growing in Nigeria are not attacked by walnut diseases that have been reported in many other parts of the world. Possibly, the quantity of walnuts produced could have been far greater than what it is presently if diseases are managed like is done for other crops of economic importance. Also, at the postharvest stage, a greater percentage of the nuts produced are lost due to fungi rots. This reduces both the quantity and quality of the nuts harvested. The absence of literatures on walnut diseases in Nigeria points to the fact that African walnut has not received the desired research attention especially in the area of disease management in Nigeria. There is need for research into the diseases affecting walnut in Nigeria. The first step to take in this regard is to isolate and identify different organisms infecting walnut and causing diseases the major aim of having the knowledge of the specific diseases, pathogen life cycles, the time and the method of their infection, the walnut parts affected and the method of causal agent dissemination.

4.2 Disease management options

The practical reason for studying crop diseases is to develop economic measures for control based on knowledge of the specific diseases with certain agronomic and economic considerations. For effective control of walnut diseases in Nigeria, the six fundamental principles of disease management have to be put in place according to their environmental adaptability; bearing in mind the guiding principles which must be kept in mind; such as: the cost of the measure not being more than the expected return, the measure not being too complicated and dangerous to use, the measure not aggravating other pest problems in the operation, and when possible, complement other production practices.

Preventing the entrance and establishment of pathogens in uninfected walnut crops in a particular area, use of certified walnut seed and most especially, refusing obviously diseased specimen will help to prevent the introduction and spread of walnut plant pathogens into Nigeria, certain federal and state laws regulate the conditions under which walnut crops may be grown and distributed between states such as quarantines, inspections of walnut plants in the field or warehouse, and occasionally by voluntary or compulsory eradication of certain host plants.

In management of crown gall disease, susceptible nursery stock known to be infested with the pathogen should not be planted in fields, all nursery stock with symptomatic roots and visible galls should be destroyed. Nursery planting sites should be rotated frequently i.e., at least in 4 to 5

years. Infested fields should be planted with grain crops for at least four years before they are planted with walnut nursery stock. Nursery stock should be budded rather than grafted because of the much greater incidence of galls on graft than on bud unions.

Removal of diseased walnut diseased plants, or parts; and by disinfection, usually by chemicals, sometimes by heat treatment. In management of walnut blight, leaf blotch and anthracnose, application of timely spray of copper-based fungicides, cutting out damaged parts and burning them, using a soil with a pH above 6, avoiding excessive nitrogen, excessive wetness and allowing for good aeration by pruning are effective management methods (34).

Use of some protective barrier between the susceptible part of the host and the pathogen such as a protective spray or dust applied to the plant in advance of the arrival of the microbial spores. There is a long list of chemicals available that can be used in present-day protective spraying and dusting, along with eradicant chemicals.

In managing stem cankers and dieback diseases, pruning should be done prior to bud break, or in mid-June after leaf expansion, dead and weak branches and those which are rubbing against others creating wounds should be removed. Sterilize pruning tools between cuts by dipping them in 10% household bleach or 70% alcohol for several minutes. After pruning and training practices, cut ends should be treated with fungicide pastes like Bordeaux paste/ paint (Puttoo and Chaudhary, 1984).

Successful disease control has also been achieved by the application of copper oxychloride, mancozeb and dithianon (21).

For management of root and crown rot involves selection of well drained sites for establishing new orchards, graft union should be kept at least 30cm above ground, diseased tissues near the ground level should be scarified during dormant stage and broad-spectrum fungicidal pastes like Bordeaux paint or paste or Chaubatia paste should be applied.

Use of disease-resistant and tolerant walnut varieties which seem to be the cheapest, easiest, and most efficient way to reduce disease losses. In management of walnut blight, cultivation of resistant cultivars if available is recommended (73;74). For effective management of shoestring root and crown rot, use of resistant rootstocks such as Eastern Black Walnut and Hinds Black California Walnut are recommended by Cimanowski *et al,* (21).

Therapy can be achieved by inoculating or treating the plant with something that will inactivate the pathogen. This is used on individual walnut plants and can't be used on a large scale. In management of walnut diseases application chemotherapy immediately after the appearance of symptoms has been recommended by Jindal *et al,* (43) to check the diseases effectively (10). In management of leaf blotch and anthracnose, successful disease control has also been achieved by the application of copper oxychloride, mancozeb and dithianon (21).

Control of insect vectors and weed hosts, especially aphids, beetles and leafhoppers known to transmit viruses and mycoplasmas from infected walnut plants with some weeds which serve as overwintering reservoirs of some viruses. For effective management of shoe string root and crown rot, plantation of new orchards in freshly cleared forest soils should be avoided, care should also be taken not to injure the basal part of the trunk or the main roots of walnut trees during cultivation; as such wounds increase the

chance of infection (21).

CONCLUSION

Several studies elsewhere have reported walnut diseases in many regions of the world where walnuts are grown with no report of such studies in Nigeria. Literatures reviewed on walnut diseases' studies reveal that no tangible research has been done on disease affecting walnut in Nigeria. This calls for conscious research focus on walnut in different areas of crop protection. There is an urgent need to conduct such studies in different parts of the country where walnut is grown to obtain substantive scientific information and data on the extent of disease where available. The knowledge of the diseases will help to determine the management efforts that could be carried out to ensure increased productivity and quality of walnut in Nigeria. Also, research on walnut diseases will help in the production of the walnut diseases map in Nigeria by capturing all the regions of the country where it is grown and the corresponding management options that will ensure profitable walnut production in Nigeria.

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