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A Survey on the Menace of Lingzhi Mushrooms on Trees in Shell Residential Area, Port Harcourt

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Abstract

Observations through routine tree surveys and reports by estate managers and residents show an increasing rate of sudden fall of healthy looking trees recently in Shell Petroleum Development Company of Nigeria Residential Area (SPDC RA), thus creating a high potential risk to lives and facility. An earlier survey had suggested that a weakening of the root system due to the presence of mushroom species of a cosmopolitan basidiomycete in the genus Ganoderma may be responsible for the tree falls. Consequently, a team was constituted for an emergency tree hazard hunt exercise using the approved criteria for tree cutting as terms of reference. During the tree hunt exercise, a survey was undertaken with the aim of identifying the mushroom species involved and type of disease, disease symptoms, method of infection/spread, any diagnostic tools for the disease as well as curative and preventive measures for the management of the disease in order to proffer suitable recommendations.

Forty-one (41) out of a total of two hundred and seventy-one (271) trees surveyed (15%) were impacted by the mushroom. Disease symptoms include yellowing, necrosis, wilting of the palms fronds and development of a basidiocarp at the tree base. The fungus is soil-borne, spreading from root to root and by migration of airborne basidiospores from basidiocarp. It overwinters in dead woody debris and tree stumps. Some diagnostic tools have been developed both in the laboratory and field for the diagnosis of this disease which include; Calorimetric method using Ethylenediamine-tetraacetic acid, Ganoderma selective media, use of Polyclinal Antibodies (PAbs) and Polymerase Chain Reaction (PCR), Remote Sensing System, application of colour indices using multispectral and thermal camera as well as tomography instrument. The use of trench system, soil mounding, fungicidal treatment and replanting techniques have great potentials in the management of this disease. Periodic checks, routine removal of basidiocarps, geo-referencing and superimposing the impacted trees positions on an existing RA Base map and replanting the cut trees to re-vegetate the environment in phases with seedlings around the camp are recommended. Proper taxonomic study on the Ganoderma species diversity in the RA environment is necessary.

Keywords: Shell Petroleum Development Company Residential Area (SPDC RA); Basidiomycete; Basidiocarp; Calorimetric method; Polyclinal Antibodies (PAbs); Polymerase Chain Reaction (PCR); Remote Sensing; Taxonomic study; etc.;

Introduction

Trees are of great economic importance and contribute immensely in the sustenance and improvement of life. They act as air purifiers by absorbing the load of carbon dioxide in the atmosphere and letting out oxygen in the food-manufacturing process of photosynthesis. Some species serve as wind-breakers as well as adding aesthetic values to the environment. Furthermore, trees provide habitat or nesting sites for many arboreal animals like squirrels, bats and birds. Therefore, plant health is crucial in environmental sustainability.

The incessant fall of trees in the Shell Petroleum Development Company (SPDC) Residential Area (RA) especially during stormy weather, became worrisome in recent times. This led to the development and approval of a Tree Management Plan (TMP) by the Biodiversity team which recommends a tree survey to be conducted every four years. This survey commenced in 2011 and was repeated in 2015. Criteria for marking of trees for cutting or trimming were developed and used for the surveys.

However, there has been an increasing rate of sudden fall of healthy-looking-unmarked trees recently, creating a high potential risk to lives and facilities in the RA [Plate 1, 2,3,4]. The 2015 survey had suggested that a weakening of the root system due to the presence of the mushrooms may have been responsible for the tree falls. A team was constituted for an emergency tree hazard hunt exercise using the approved criteria for tree cutting as terms of reference (Appendix 1). During the tree hazard hunt exercise, it was observed that a good number of trees including the sudden fallen ones had signs of mushrooms growing on the stem [Plate 5] or at and around their bases especially the oil palms.

Plate 1: Tree fall across the road

Plate 2: Tree fall with impact on telecom panel

Plate 3: Tree fall by a residential building

Plate 4: Tree fall on a perimeter fence

Plate 5: Fallen tree with mushroom growing at the base of stem

Shell Petroleum Development Company Residential Area (SPDC RA) is one of the habitats for biodiversity conservation in Nigeria. Built in the early sixties, it is around eleven and half square kilometres and is home to a lot of diverse trees and minor animal species that are highly protected. It is located at the Rain Forest belt of Nigeria. This paper focuses on efforts to conserve the plant species through surveying and identifying diseased species, their treatment, early detection, felling for safety purposes and replanting. SPDC RA is one of the habitats for biodiversity conservation in Nigeria.

Objectives of the Study

This study has the following objectives:

- Identify the mushroom species involved and type of disease.
- Determine the disease symptoms and method of infection / spread
- Determine if there are diagnostic tools for the disease.
- Identify curative and preventive measures for the management of the disease and proffer suitable recommendations.

Materials and Methods

Study Area

The SPDC RA is one of the largest and oldest estates in Port Harcourt – capital city of the Rivers State of Nigeria. It is located just a few degrees north of the equator with the coordinates: 04o 51.334' N; 007o02.910' E [Figure 1]. It was established in the early sixties, shortly after oil was first struck at Oloibiri. The estate covers an area of 11.7 km^2 in Rumuokwurusi, Obio / Akpor Local Government area, within the lowland rainforest zone. Most of the original forest trees were retained and embedded in the physical development of the area and several ornamental and economic trees were planted in the course of landscaping. Today, the RA has become a biodiversity rich area of Port Harcourt, with its serene and nerve-soothing environment, well maintained streets, drainages, lawns, gardens, and recreational areas. The residence and recreational areas are so shaded by trees that new helicopters operators hovering over the area would hardly locate the helipad.

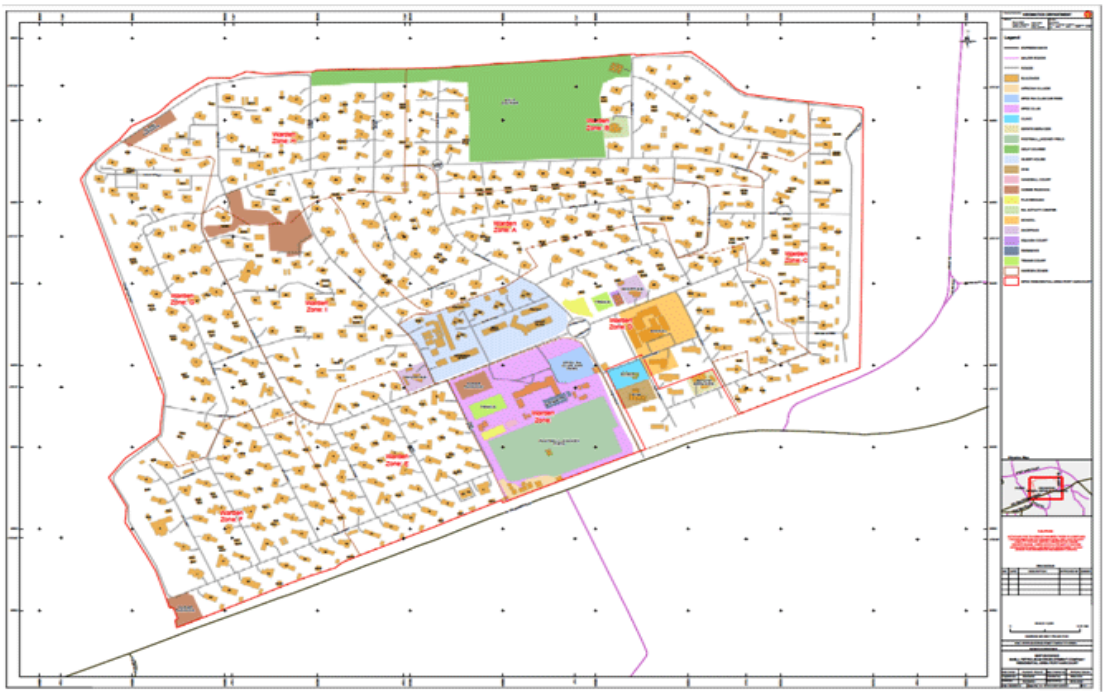

Figure 1: Location map of Shell RA

The RA falls within the tropical rainforest zone. The south-west wind which blows across the area brings a lot of rain, often torrential, between May to October with peaks in July and September. Winds with speed of 11 – 16 knots (5.5 – 7.9 m/s) and above occur occasionally, especially during the onset of heavy rainfall (NDES, 1998)[14].

Materials for the Study

The materials used for the survey were probe sticks, machetes, a digital camera, field notebooks and writing tools.

Field Survey and Data collection

The field survey was conducted between the month of May and August, 2016. This survey was done by observations and transects walks in and around the RA with field assistants conversant with the camp. Voucher specimens were collected and identified using morphological characteristics and standard mycological manual by Dickson and Lucas (1982)[5]. The number of trees showing the presence of mushrooms was recorded. Photographic documentation of various trees affected by the mushrooms was also taken using the digital camera.

Data Analysis

The data collected in this study were descriptive in nature, hence they were explained directly.

Results and Discussion

The Mushrooms

The mushrooms are called *LingZhi* in China or *Reishi* in Japan. Some of them are used in traditional and herbal medicine while several others are plant pathogenic species. *LingZhi* in China means "Spiritual herb". *Zhi* refers to *Ganoderma lucidum* to symbolize good fortune. It is also called *Ruicao* which in China means "auspicious plant" (*rui* meaning Auspicious or Felicitous omen and *cao* meaning plant or herb) LingZhi is also associated with health and healing, happiness, long life and as well as immortality. The LingZhi (*Reishi*) mushrooms actually consist of closely related species of the fungus *Ganoderma.* The genus *Ganoderma* (Class-Basidiomycetes, Order-Aphyllophyrales and Family-Ganodermataceae) is a cosmopolitan basidiomycetes called "white rot" fungi which degrades lignin, cellulose and polysaccharide component of many woody plants [13]. *Ganoderma* spp lives in the soil as a saprophyte with no ill effect until it encounters live roots. The fungus colonizes a plant root system slowly causing basal stem rot disease [BSR., Plate 6] and may take several years (10-20yrs) to finally kill a tree. It causes significant damage to our shade trees by destroying a tree's structural root system. Trees have two primary root systems: The structural system, responsible for anchoring a tree to the earth and a Feeder root system responsible for the daily demands of moisture and nutrients. Once the structural root system has been compromised, a tree's stability becomes a concern.

The fungus produces a fruiting structure (a fungal conk) near the base of the tree. Conks are mushrooms that have pores instead of gills on their underside. It is a shelf-like structure that varies in colour and size from rusty-orange, red to a dark-red with cream coloration almost always shiny in appearance [Plate 7].

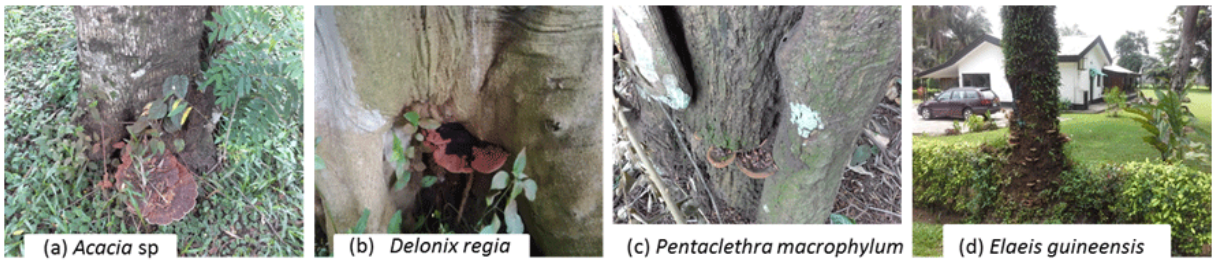

Plate 6: Basal stem rot disease of various economic trees

Plate 7: Various types and colours of Ganoderma basidiocarp

Ganoderma is a devastating soil-borne pathogen widely distributed both in tropical and temperate regions. Various researchers have reported varied numbers of *Ganoderma* species all over the world [9]. Twenty (20) species have been reported in Malaysia, some reported 80 *spp* and others 300 *spp.* The Index Fungorum database maintained at Royal Botanic Garden Kew, U.K enlisted 403 spp while Mycobank, which is the International Mycological Association's database (CBS) fungal biodiversity centre Netherlands, gave 354 *spp*. [9]. Nevertheless about 15 spp have been involved in basal stem rot disease [16, 13]. These include: *G.applanatum, G.boninense, G.chalceum, G.cochlear, G.pseudaferreum, G.tornatum, G.fornicatum, G.lucidum* among others of which G.boninense is the most destructive pathogen in Oil Palm [17].

Disease Hosts

The fungus causes basal stem rot disease and mortality of many economic trees and perennial crops [Table 1]. Forty-one (41) out of a total of two hundred and seventy-one (271) trees hunted which is about 15% were impacted by the mushroom. Severity of infection was more on oil palms with 68% and flamboyant trees with 19%than other trees. About 34 plant genera including palms (Oil palm, Coconut, Betel nut), Rubber, Cocoa, Tea, Coffee, *Acacia* and *Albizia* among others have been implicated as hosts of *Ganoderma*spp [12, 9].

Table 1: Trees in Shell RA showing presence of Lingzhi Mushrooms

	Name of plant				
S/No	**Common Name**	**Botanical Name**	**Family**	**Number of trees**	**% Occurrence**
1	Acacia	*Acacia sp*	Fabaceae	1	2.44
2	African oil bean	*Pentaclethra macrophylla*	Fabaceae	1	2.44
3	African oil palm	*Elaeis guineensis*	Arecaceae	28	68.29
4	Avocado pear	*Persea americana*	Lauraceae	1	2.44
5	Coconut	*Cocus nucifera*	Arecaceae	2	4.88
6	Flamboyant	*Delonix regia*	Fabaceae	8	19.51
Total number of trees Impacted				**41**	15.13
Total number of trees Hunted				**271**	

Morphology

At the early stage, the basidiocarp appears as small white buttons [Plate 8] which develops rapidly into a bracket-shaped sporophore [Plate 9].Ganoderma sporophore consists of the stalk or stipe and the brackets (pileus or cap) produced from the stalk. The upper side of the sporophore is light to dark brown in colour depending on the species while the underside is white in colour. Upper surface is known as laccate which forms a shiny appearance when young and turns brown when spores are being produced, [Plate 10].

Plate 8: Fruiting body of Ganoderma-Small white buttons

Plate 9: Bracket- shaped Basidiocarp

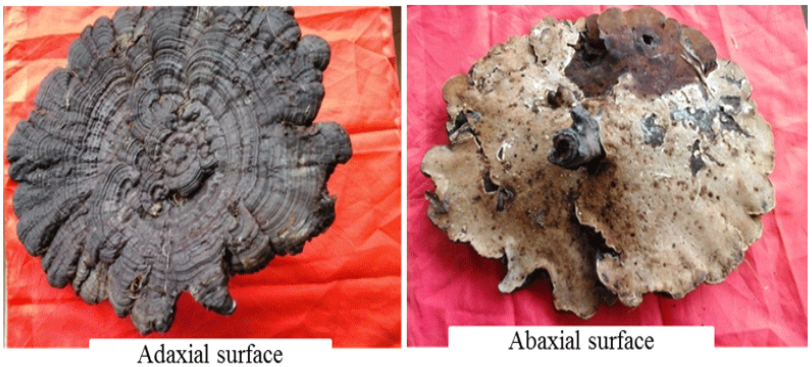

Plate 10: Basidiocarp of *Ganoderma* sp

Method of Spread and Mechanism of Action

The mode of infection comprises of vegetative spread of the pathogen from root to root contact and migration of airborne basidiospores from the basidiocarp. The Ganoderma fungus is a facultative parasite that can live as a saprophyte on rotting stumps and roots but when a suitable host becomes available, it will colonize the host and establish a parasitic relation (Naher et al, 2013). The fruiting body (Basidiocarp), is formed on the exterior of the trunk and from there, releases the spores (basidiospores) which spread on the soil or to nearby trees [3, 13, 15] opined that the root infection by Ganoderma spp occur in three.

Aggressive Necrotrophic Stage

This involves intensive host cell wall degradation.

Third Phase

This is the formation of melanised mycelium both within host tissues and on external roots in form of very tough pseudo-sclerotia. For a successful penetration and degradation of intact roots, production of an array of cell wall-degrading enzymes including lignases and polysaccharidases occurs. The production of Manganses peroxides (mnp) and laccaseswhich contributes to melanin formationhave been reported in G. lucidum [3].

Disease Symptoms

The basal stem rot (BSR) disease caused by Ganoderma spp is a root disease which includes the infection of the basal stem. The disease has the following symptoms as shown in oil palms:

- Failure of the young leaves to open.
- Leaves turn yellow.
- Necrosis of the leaves upwards through the crown
- Wilting of the frond. [Plate 11]

Plate 11: Oil palm infected by BSR- Wilted fronds

The disease progresses slowly but eventually all the affected palms die. The attack by the fungus resulted in dry rot of internal tissues around the base of the palms [Plate 12] which can cause the affected palms to easily topple during stormy weather. Young palms once infected usually die within 6-24 months after the first appearance of symptoms whereas mature palms are more resistant and can survive for 2-3years or more. The pathogen can be present in symptomless, naturally-infected mature trees hence BSR is called a silent killer of oil palm plants [12]. Similarly, this disease has been referred to as a cancer because it is very difficult to detect at the early stage of development and by the time the disease symptoms are apparent, more than half of the plant's internal tissues are already rotten [7]. The appearance of the basidocarp at the base of the stem is a more evident symptom appearance which darkens with age [Plate 13]. The basidiocarp can develop from the area of stem base or from infected root. The formation of the fruiting structure reflects the position of the infection within the stem. It was observed that if the fallen trees [Plate 14] or stumps [Plate 15] were left to rot in the field, various fruiting bodies of Ganoderma may be produced and thrive.

Plate 12: Dry rot of internal tissues of oil palm

Plate 13: Basidiocarp that darkens with age

Plate 14: Basidiocarp of Ganoderma sp. growing on a fallen tree

Plate 15: Basidiocarp of Ganoderma sp. growing on old tree stumps

Diagnostic Measures

Some conventional diagnostic tools have been developed for the diagnosis of Basal Stem Rot disease [12]. These include:

- The Calorimetric method using Ethylenediamine-tetraacetic acid (EDTA)- this has been used to detect Ganoderma sp. in coconut.
- Semi- selective media for Ganoderma cultures from oil palms.
- Ganoderma Selective Media (GSM) which can detect the pathogen from any infected tissues. GSM can detect Ganoderma in oil palms that are infected but have not shown any external symptoms. These methods are not recommended for large scale application due to low accuracy. Similarly, advanced molecular techniques have been innovated with more accuracy of detection and fungal identification. Two of these techniques are
- Use of Polyclinal Antibodies (PAbs) in the pathogen: using enzyme-linked immune-sorbent assay (ELISA)
- Use of Polymerase Chain Reaction (PCR) methods using specific deoxyribose nucleic acid sequences of the pathogen. All the above methods are laboratory based techniques [7].
- Remote Sense System or e Nose system - is being used to detect real time disease monitoring in Agriculture technology. Nevertheless, noted that e nose system can discriminate the Ganoderma infected plant in the field condition but is not able to detect the stages of infection levels or early infection of the disease [1].
- The application of colour indices using multispectral and thermal camera to separate healthy and BSR-infected trees has been reported [8].
- Use of Tomography instrument: Some methods based on sound velocity measurements have been introduced in the practice of tree assessment by using sonic tomography instrument called PiCUS Sonic Tomograph [4, 10]. The instrument consists of a set of sensors that are strategically placed around a tree trunk to detect the internal lesion of BSR. The data were then displayed into a tomogram with three (3) categories of colours indicating a healthy or solid wood (black / brown), decrease in densities (green) and degraded wood (violet / blue / white). The entire colours are categorized based on the different velocities of the sound wave. By understanding the tomogram, the status of a tree (whether it is healthy, decrease of density or unhealthy) can be promptly determined [6].

Practical Approach to Control Measures

It is pertinent to note that there is dearth of information on efficient measures to eliminate the disease. Nevertheless, studies have shown that various methods have great potentials for the management of this disease [13]. These include:

- Trench System
- Soil mounding
- Removal of Basidiocarp
- Fungicidal treatment
- Replanting techniques

Trenches: Digging trenches around infected trees to prevent mycelium spread by root contact with neighbouring healthy trees has been recommended. Trenches should be 2m x 2m with 0.5m wide and 1m in length (in older trees) and 4m x 4m with 30cm wide and 75cm in length (in younger trees) [13].

Soil Mounding: Mounding of soil near adjacent area of the trees to make slop of 75cm in height and 1m in radius from the base land. Soil mounding prolongs and protects the weakened boles [2].

Removal of Basidiocarp: Based on several studies on Ganoderma species diversity, basidiospores were implicated directly or indirectly in basal stem rot infections. Therefore, removal of basidiocarp routinely will reduce basidiospores spread which eventually bring about inoculum reduction of the pathogen [3].

Fungicidal Treatment: Screening of fungicides against Ganodermain-vitro showed that numerous fungicides strongly inhibit their spread. Such fungicides include: bromocomazole, carbendazim, benomyl tridemorph and hexaconazole among others. The trunk injection technique using pressure injector [Plate 16] to apply systemic fungicide helped to limit the spread of Ganoderma infections [13]. This apparatus which was capable of delivering fungicides to the affected part quickly and effectively was developed by Malaysian Oil Board (MPOB). Bromoconazole and hexaconazole were reported to be the most effective in giving a significant reduction in BSR incidence.

Plate 16: Control of Ganoderma in existing stand using fungicide hexaconazole trunk injection with hand knock injector which attached to the Motorized Knapsack Sprayer

Replanting Techniques: To reduce the risk of Ganoderma Basal Stem Rot infections, proper technique of sanitation has been recommended by MPOB to be adopted during planting or replanting. At replanting, all old tree tissues are to be destroyed by shredding the trunk, stumps and roots into small fragments and allowed to decompose. When the stumps and roots have been extracted, a pit of 1.5m x 1.5m x 1.5m is dug and refilled with nearby soil [Plate 17]. New plants are then planted away from the former planting points [Plate 18]. BSR infection occurs by mycelia development through root contact, thus sanitation during replanting is an important measure for the disease management [2, 9].

Plate 17: Control of BSR in existing stand by removal of diseased palm using excavator: pushing, excavating and refilling with nearby soil

Plate 18: Control of BSR at replanting: excavating, ploughing and planting new palm along ploughing areas

Conclusion

This study recorded 15% incidence of Lingzhi mushroom infestation on trees in SPDC RA especially oil palms and flamboyant trees among others. Regardless of species or host plants, the fungus causes significant damage to our trees by destroying their structural root system. The fungus is a facultative parasite and in the absence of living roots can live on dead woody debris and tree stumps. The infection occurs by mycelial development through root contact and sometimes by basidiospores produced in the bacidiocarp. The basidocarp is the most identifiable structure of the fungus which on appearance indicates that more than 50% of the plant internal tissues are already rotten. BSR disease has been described as lethal and incurable, a cancer which is very difficult to detect at the early stage hence a limiting factor in the disease control. It is called a silent killer because the pathogen can be present in symptomless naturally-infected mature trees.

Some common methods used to detect BSR disease included morphological and molecular techniques as well as use of tomography instrument have been documented. The use of various control techniques can only prolong the life of infected trees by delaying the progress of infection. Therefore, only the re-planting method in which infected trees must be cut, destroyed and carted away while new seedlings are planted away from the former planting points has the greatest potential in the disease management.

Recommendations

Periodic Checks:

- Individual inspection of trees by inmates of a household around their houses for presence of mushrooms and report to RA Site management.
- Inspection of trees periodically especially at the onset of rains each year looking out for the presence of mushrooms at the base of trees by the Estate Management Team in the RA.

Removal of Basidiocarp: Routinely is necessary to avoid the build-up of large inoculum source for infection.

Replanting the Cut Trees is Necessary for the Re-Vegetation the Environment:

- Replanting process can be done in phases to manage the cost.
- Scouting around the camp to search for germinated seedlings especially the oil palms which could be nurtured as replacement.
- Proper technique of sanitation should be adopted during planting or replanting

Use of Instrument: To determine the health status of a tree is recommended (if affordable). The Biodiversity Team previously recommended the use of Tree Radar Unit for this purpose.

Geo-Referencing Impacted Trees and Superimposing Trees Positions on an RA Base Map: This will determine the extent/direction of spread and help in the control. This will involve engaging the services of Geomatics team (UPO/G/DGG) for the mapping of co-ordinate positions of the impacted trees and subsequently producing a base map showing the locations of such trees.

Further Studies Recommended: Proper taxonomic studies of the Ganoderma species diversity in the RA environment.

Appendix 1: Criteria / guidelines for marking of trees in Shell Residential Areas

Decision to fell trees is based on the following risk factors, in six categories.

Decision to fell trees is based on the following risk factors, in six categories.	
Category	**Tree Status/condition**
Category I	Trees very close to houses / facilities / infrastructure ; less than 10m from the pavement / wall; precariously inclined thereby constituting danger to lives and property in the event of a fall
Category II	Trees severely diseased or attacked by any type of pest – termites, ants, wood-borers, parasitic plants, stranglers, bacteria, fungi (e.g. *LingZhi* mushrooms), viruses, etc.
Category III	Very tall, massive, old trees with strong evidence of weakness, rottenness, holes in stems / branches.
Category IV	Trees completely or partially defoliated, with branches already breaking off.
Category V	Trees with evidence of instability in the root system; weak anchorage, root rot, etc. making them prone to uprooting by wind and storm.
Category VI	Trees with extensive root systems threatening the integrity of building foundations, pavements, septic tanks, gutters, and other facilities.

B: Pruning / Trimming

Trees marked for pruning are those:

- Which are overgrown, constituting potential hazards to lives and properties, with branches resting on or hanging over the roof.
- With wounds, termites / ant nests, plant parasites, etc. to be pruned off.
- Having mild infestation of termites, ants, wood-borers, plant parasites, etc.
- Which size and growth direction need to be controlled.
- Which need to be rejuvenated, by increasing light penetration and air circulation around them.

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