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Evaluation of Some Termite Resistant Timber Species of Myanmar and their Chemical Composition

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မြန်မာ့ကျွန်းသစ်သည် ကမ္ဘာကျော်သော သစ်တစ်မျိုးဖြစ်ပါသည်။ မြန်မာ့ကျွန်းသစ် ကမ္ဘာကျော်ရခြင်းမှာ ပရိဘောဂပြုလုပ်ရန်လှပခြင်း၊ ပြင်ပရာသီဉတုတွင်အသုံးပြုရန် ခိုင်ခံ့မှုရှိခြင်း၊ အလုပ်လုပ်ရန်လွယ်ကူခြင်း၊ ကျုံ့ခြင်း၊ ကွဲခြင်းနည်းပြီး ပုံသဏ္ဍာန်တည်မြဲမှုရှိခြင်း၊ ခြစားမှုဒဏ်ခံနိုင်ခြင်းတို့ကြောင့်ဖြစ်သည်။ ကျွန်းသစ်၏ ခြစားခံနိုင်ခြင်းသည် ၎င်းတွင် အင်သရာကွီနုန်းဒြပ်ပေါင်း ပါဝင်သောကြောင့်ဖြစ်ကြောင်းသိရပါသည်။ ဤသုတေသနကို လူသုံးနည်း သစ်မျိုးအချို့၏ ခြစားခံနိုင်မှုကိုလေ့လာရန်၊ ခြစားခံနိုင်သော သစ်မျိုးများ၏ ဓာတုဒြပ်ပေါင်းပါဝင်မှုကိုလေ့လာရန်၊ ကျွန်းသစ်တွင်ပါဝင်သော ဓာတုဒြပ်ပေါင်းများနှင့် နှိုင်းယှဉ်လေ့လာရန်ဟူသည့် ရည်ရွယ်ချက်များဖြင့်ဆောင်ရွက်ခဲ့ပါသည်။ ခြစားမှုခံနိုင်စွမ်းကို မြေမြှုပ်စမ်းသပ်နည်း (under-ground method) ဖြင့် စမ်းသပ်ပါသည်။ စမ်းသပ်ထားသော သစ်မျိုးများအနက် ထောက်ကြန့်၊ သင်ကန်း၊ ယမနေ၊ တောင်ဖက်ဝန်း၊ သစ်ခါး၊ ပိတောက်၊ သစ်ဖယောင်း၊ ဖန်ခါး၊ ဇောင်းပလွေး၊ လယ်ဇ၊ အင်ကြင်း၊ ကြို့ နှင့် နှော စသည့် သစ်မျိုးများသည် ခြစားမှုမရှိကြောင်းတွေ့ရပါသည်။ ခြစားမှုဒဏ်ခံနိုင်သော သစ်မျိုးများအား မီသနောပျော်ရည်သုံး၍ extraction ပြုလုပ်ပြီး ရရှိလာသော extract များတွင် ဖီနော၊ ဖလိုဗိုနိုက်စသည့် ဓာတုဒြပ်ပေါင်းပါဝင်မှုကို တိုင်းတာခဲ့ပါသည်။

Evaluation of Some Termite Resistant Lesser Used Species and Their Chemical Compositions

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Abstracts

Termites cause serious damage to wood and wood products. In recent years, natural extractives from wood species with inherent resistance to termites have been widely investigated. Wood extractives are naturally formed in trees and may be environmentally friendly after application. There are many plants that have been investigated for termiticidal preservatives, such as vetiver grass oil (Zhu, 2001); seeds (Vanucci, 1992); wood leaves, such as leaves of tarbush (*Flourensia cernua*) (Tellez, 2001); mature leaves of 7 species of Eucalyptus (Lin, 1998); leaves of *Azadirachta excelsa* (Jack) Jacobs (Sajap, 2000); and heartwood from trees. The heartwood of old-growth teak (*Tectona grandis*) is well-known for its natural durability. Teak heartwood contains a number of toxic extractives (Rudman and Dacosta, 1959; Hillis, 1987; Thevenon *et al.* 2001). Tectoquinone, a potent insecticide extractive found in teak, is highly repellent to the dry-wood termite (Wolcott, 1955) and to the subterranean-termite (Sandermann and Dietrichs, 1957). Haupt *et al.* (2003) also evaluated the role of tectoquinone in relation to durability and Tectoquinone yield was high in specimens with high natural durability. In this study, the termite resistant of some Myanmar Timber Species were tested using underground method. Among them, *Htaukkyan, Thingan, Ingyin, Yemane, Taung pet wun, thitkha, Padauk, Thitpayaung, Panga, Zaungbale, Leza, Gyo and Hnaw* were resistant to termite.

Evaluation of Some Termite Resistant Lesser Used Species and Their Chemical Compositions

1. Introduction

Termites cause serious damage to wood and wood products. Indeed termites are known to cause more damage to woody lingo-cellulosic materials than perhaps any other tropical insect groups (Tho. & Kirton, 1990). In the tropic, termites, particularly the subterranean species, poses a far more serious threat to building timbers than decay fungi. In Myanmar, termite infestations have also caused severe losses to wooden structures and furniture.

Teak (*Tectona grandis* Lin f.) is one of the most durable timbers in the world and also the principal commercial timber in Myanmar. Some of its characteristics play a key role in defining the suitability of this timber species for specific end-uses. One of the most commonly cited characteristics of teak wood is its natural durability. It offers very good resistance to weather, termites and decay, which means that it can be used externally without any treatment, increasing its commercial value. Teak is valued for its natural termite resistance properties. There is no doubt that this advantage can be attributed to extractives. Extractives in the heartwood are believed to be responsible for its termite resistance.

Haupt et al, (2003) found that total extractives content in plantation teak was 9.4% (wt/wt), while the old growth had 14.1%. Teak heartwood contains a number of toxic extractives (Rudman and Da Costa, 1959; Hillis, 1987; Thevenon*et al*, 2001). Tectoquinone, a potent insecticide extractive found in teak, is highly repellent to the dry - wood termite (Wolcott, 1955) and to the subterranean termite (Sandermann and Diedrichs, 1957). The most abundant compound in teak methanol extract was 2-methyl anthraquinone (MyoAung, 1991). Almost all of the anthraquinones found in the wood are effective against termites.

In collaboration with ITTO and Forest Department, a project entitled "Introducing Myanmar's lesser used Timber Species to the World Market" was carried out. Under this project, the durability of fifty-four lesser used timber species were tested using two methods viz: laboratory decay test and field graveyard test. The durability classes were classified based on combined effect. Aung Soe & Cho Cho Win (2004) studied the graveyard test at *Letpankon* Forest Research Station and they stated that *Thitpayaung* and *Taungpeinne* were termite resistant after 5 years test. Although Win Kyi-2 (2006) stated that *Gangaw*, *Thitya*, *Ingyin*, *Padauk*, *Pyinkado*, *Taukkyan* and *Thitkha* were resistant to termite, no specific scientific research work has been done.

Therefore, the selection of the termite resistant species is the primary objective and the most effective wood species proposed in this study will form a basis for termiticidal plants to be used in termite control. Findings obtained in this study could be used on pilot production trials and testing with the ultimate aim of producing local alternative materials for the control of termites in wood preservation sector.

The objectives of this study were to supply background information on the natural resistance of different types of native woods to termite feeding, to compare the anthraquinone composition in each species with in teak, to determine the basic phytochemical compositions of the wood extracts and to identify the key chemical compounds responsible for the anti-termite properties of the most efficacious extract.

2. Literature Review

2.1. Termite damages

Termites are social insects belonging to the order Isoptera. Termites occurs throughout the tropics and common in many subtropical and warm temperate countries.The damage they caused to wooden structures throughout the warmer regions of the world is incalculable. Termites inhabit approximately 70% of the world, mainly in the tropical and sub-tropical regions extending to some areas in the temperate region (Lee and Ryu 2003). There are now over 2700 species of termites described from 282 genera but these can be grouped in four major categories according to their nesting habitats and association with moisture. These are damp wood, dry wood, subterranean and arboreal termites (Haverty et al. 2005).

Damp wood termites also called wet wood termites live and feed on very moist wood especially stumps and fallen trees on the forest floor. They live in and feed on rotten logs or highly moist timber in soil. Species in this ecological group are composed of two families of termites, Termopsidae and Kalotermitidae. The pest status for this group is minor compared to the other termite groups (Goulding et al. 1973).

Dry wood termites (Family: Kalotermitidae) are found commonly on most continents. They do not require contact with moisture or soil in order to survive and they have a low moisture requirement and can tolerate dry conditions for prolonged periods. They nest entirely in timber above ground. They infest dry, sound wood, including structural lumber, shade and orchard trees, utility poles, posts, and lumber in storage. Piles of their faecal pellets, which are distinctive in appearance, may be a clue to their presence. (Bach 1990).

Subterranean termites are found practically throughout the tropical and temperate parts of the world (Parman and Vargo 2008). They require a source of moisture in their environment. To satisfy this need, they usually nest in or near the soil and tend to reach their food sources from the underlying soil. They maintain some connection with the soil through tunnels in wood or through shelter tubes that they construct. These shelter tubes are made of soil with bits of wood and termite faecal material (Haverty et al. 2005). There are several genera of subterranean termites found in the literature. They include *Coptotermes, Odontotermes, Microtermes, Recticulitermes and Hetrotermes* (Su et al. 2000; Haverty et al. 2005). Subterranean termites are the most widely distributed of all the forms and it has been estimated that they caused 95% of all the damages attributed to termites. Subterranean termites are by far the most economically important family of termites (Appendix).

2.2. Termite resistant timber

No timber is wholly and permanent immune from termite attack, but the heartwood of some species is very resistant and is unlikely to be attacked in a building. There are wood species that are naturally resistant to bio-deterioration agents. The resistance is mainly due to the accumulation of extractives in the heartwood, some of which are decay inhibitors (Kityo and Plumptre 1997). It is these extractives which render the heartwood unpalatable to wood destroying organisms. Hinterstoisser *et al.* (2000) noted that the content of extractives plays a key role in the prediction of the durability of wood. The concentration of extractives varies among species, between individual trees of the same species and within a single tree. Many types of wood have their own natural defenses against insects and other pest species. This is especially true in tropical environments because there is no frost season to keep pest populations down (Beal et al., 1974).

According to W.P.K. Findley(1985), *Tectona grandis* (Teak), *Adina cordifolia* (Hnaw), *Albizia procera* (Sit), *Cedrela toona* (Thitkado), *Dalbergia latifolia*, *Hopia odorata* (Thingan), *Pterocarpus indicus* and *Shorea* (certain spp) are naturally durable species in the region of India, Myanmar and Malaysia.

2.3. Wood Extractives

Wood is a natural organic material that consists mainly of two groups of organic compounds: carbohydrates (hemicelluloses and cellulose) and phenols (lignin), that correspond to (65-75%) and (20-30%), respectively (Petersen, 1984). The wood is also constituted of minor amounts of extraneous materials, mostly in the form of organic extractives (usually 4–10%) and inorganic minerals (ash), mainly calcium, potassium, and magnesium, besides manganese and silica.

The concentration of extractives varies among species, between individual trees of the same species and within a single tree. Some of these extractives render the heartwood unpalatable to wood destroying organisms. Factors affecting wood consumption by termites and fungi are numerous and complexly related. The amount however can vary from season to season even in the same tissue or are restricted in certain wood species (Taylor et al, 2006).

Extractives are low molecular weight compounds present in wood (Chang et al, 2001), also called secondary metabolites, and are indeed crucial for many important functional aspects of plant life. The relationship between extractives and natural durability of wood was first reported by Hawley et al (1924). The natural durability of wood is often related with its toxic extractive components (Scheffer and Cowling 1966; Carter et al, 1978; Hillis 1987; McDaniel 1992; Taylor 2006; Santana et al, 2010).

But, the natural durability is extremely complex and additional factors such as density of wood and lignin content, besides this dual fungicidal and antioxidant action, may be involved (Schultz and Nicholas 2002). Several authors investigated the relationships between the wood properties and extractives (Carter et al, 1978; Schultz et al, 1990; Reyes-Chilpa et al, 1998; Chang et al, 1999; Morimoto et al, 2006). Several woods contain extractives which are toxic or deterrent for termites, bacteria and fungi resistance (Maranhão 2013; Taylor et al, 2006).

Humans have been using plant extracts as insecticides since before the time of ancient Romans. People applied the crude mixture called essential oil from natural products in antifungal, antimicrobial, and insecticidal activities (Franzios, 1997). There are many plants that have been investigated for termiticidal preservatives, such as vetiver grass oil (Zhu, 2001); seeds (Vanucci, 1992); wood leaves, such as leaves of tarbush (*Flourensiacernua*) (Tellez, 2001); mature leaves of 7 species of Eucalyptus (Lin, 1998); leaves of *Azadirachta excels* (Jack) Jacobs (Sajap, 2000); and heartwood from trees.

Many species of wood have been extracted, and the efficacy for termite resistance has been tested. These woods include *Taxodium distichum* (L.), (Scheffrahn, 1988); Sawara wood (*Chamaecyparispisifera* D. Don) (Saeki, 1973); Port-Orford-cedar [*Chamaecyparis lawsoniana* (A. Murr.) Parl.](McDniel, 1989), bogwood of yakusugi (Yatagai, 1991); *Diospyros virginiana* L. (Common persimmon) (Carter, 1978), *Mansonia altissima* and *Piptadeniastrum africanum* (Bultman, 1979); *Juniperus procera* (African pencil cedar) (Kinyanjui, 2000); Taiwania (*T. cryptomerioides*) (Chang, 2001); Melaleuca (*Melaleuca quinquenervia*) heartwood blocks (Carter, 1982); *Lophopetalum wightianum*, *Micro-cerotermesbeesoni* Snyder, *Neotermesbosei*(Snyder) and *Heterotermes indicola* (Wasm.) (Sen-Sarma, 1979); Brazil wood (*Prosopis juliflora*), *Anadenanthera macrocarpa*; *Astronium* *urundeuva*; *Schinopsis brasiliensis*, *Senna siamea*, *Tabebuia aurea*, *Amburana cearensis*, *Tabebuia impetiginosa* and *Aspidosperma pyrifolium* (Paes, 2001).

2.4. Antitermitic Compound

Many kinds of chemicals are found to be termiticidal due to different resources used. The extracted chemicals may act as feeding deterrent, oviposition deterrents, repellent and toxicant.

Anthraquinone naturally occurs in some plants (e.g. aloe, senna, rhubarb, and Cascara buckthorn), fungi, lichens, and insects, where it serves as a basic skeleton for their pigments. Natural anthraquinone derivatives tend to have laxative effects and trade names Hoelite, Morkit, Corbit, and others. Various types of quinones (benzoquinones, naphthoquinones, or anthraquinones) occur in many plant families (Toshiaki 2001).

Termite resistant woods are said to contain quinones that possess natural repellent and toxic properties (Carter et al, 1978; Scheffrahn 1991; Ganapy et al, 2004; Dungani et al, 2012). Tectoquinone, anthraquinone, presented strong antitermitic activity and is assumed to be at the origin of the resistance of teak wood to termites (Haupt et al, 2003; Kokutse et al, 2006). According to Wolcott (1955) this substance is highly repellent to the dry-wood termite *Cryptotermes brevis* (Walker) and Sandermann and Dietrichs (1957) demonstrated its toxicity to subterranean termite *Reticulitermes flavipes*. Castillo and Rossini (2010) isolated naphthoquinones from heartwood of *Catalpa bignonioides* (Bignoniaceae) that showed activity against the termite *Reticulitermes flavipes*. The most abundant and active termiticidal compounds were catalponol and catalponone.

Nathan Shook Little (2010) stated that the termite, R. flavipes instinctively avoids wood which contains high levels of antioxidants, such as heartwood with **phenolic extractives.** These chemicals include **Terpene** (Sharma, 1994), α-terpineol and three sesquiterpene alcohols T-cadinol, torreyol (δ-cadinol), and α-cadinol (McDaniel, 1989), 7-methyljuglone, isodiospyrin (Carter, 1978), cedrol and alpha-cadinol (Chang, 2001), alpha–pinene, p-cymene and 1,8- cineole (Lin, 1998), and aphthalene (Henderson, 1998). These compositions may have different effects on different species of termites.

Flavonoids have an important effect on the durability of wood (Chang et al, 2001; Wang et al, 2004). The heartwood of *Lonchocarpus castilloi* Standley (Leguminosae) which has two flavonoid, is highly resistant to attack by the dry wood termites that presented feeding deterrent activity to those termites *(*Reves-Chilpa et al, 1995). Ohmura et al (2000) examined the antifeedant activity of some flavonoids against the subterranean termite with no-choice tests and two-choice tests and reported that flavonoids present in *Larix leptolepis* (Pinaceae) wood, showed strong feeding deterrent activities against the subterranean termite, and suggested that some flavonoids such as quercetin and taxifolin might be useful for termite control agents considering their abundance in plants. The heartwood of *Acacia auriculiformis* (Leguminosae) has been shown to contain a number of different flavonoids and proanthocyanidins content (Sarai et al, 1980; Barry et al, 2005).

Saponins are glycosides with a distinctive foaming characteristic. Saponins are bitter and reduce the palatability of livestock feeds. Some saponins reduce the feed intake and growth rate of nonruminant animals while others are not very harmful. (Wickremasinghe and Thirugnanasuntheram 1980; Magalhaes et al. 2003).

Similarly, the synthesis of **triterpenoid** saponins showed the greatest antifeedant activity with *R. speratus*, and the activity decreased according to the lengthening of the chain of the sugar moiety (Ohmura et al. 1997). These studies suggest that the number of sugar chains, halogenation and carbon-chain length in the chemical structure of the active component are the factors affecting the antitermitic activity (Ohmura et al 1997).

Alkaloids have a range of antimicrobial and insecticidal properties including antifeedant and toxic properties and have potential for commercial development as wood treatment agents (Yang et al. 2002; Kim and Mullin 2003; Mao and Henderson 2007).

3. Materials and Methods

This stage involved sample collection, identification and preparation of samples preparing the termite testing site.

3.1. Sample Collection

In this study, thirty timber species of Myanmar were studied. The tested species were collected under the project entitled "Myanmar lesser used timber species to the world market". The wood samples have been authenticated at Herbarium and Anatomy Section of Forest Research Institute (FRI), Yezin.

In (*Dipterocarpus tuberculatus.*Roxb) is well known to be very susceptible to termite attack, the sapwood being more susceptible than the heartwood therefore, the blocks of In (*Dipterocarpus tuberculatus.* Roxb) was used as bait wood to compare. These plants were selected because they have been reported to be used locally in Myanmar to protect against termites.

3.2. Sample Preparation

Sample preparation was carried out at Saw-mill of FRI. 20mm x20mm x20 mm blocks were prepared. Fifteen replications were selected for each species. These blocks were free from knots, drying defects and without visible evidence of fungus infection. All the test blocks were conditioned by oven-drying for 48 hours at 60ºC and weighed periodically until constant weights were attained. These test blocks were used for the field test.

3.3. Site Preparation

A test site at FRI, highly susceptible to subterranean termites was chosen for study. The design of the field test procedure is as follows: a ditch of consistently 15-20 cm depth is dug to partly layer with residues from coconut fibers and susceptible wood veneers (to bait and aggregate termites). After two weeks later, the bait veneers were covered with termites. The site was ready to test.

3.4. Evaluation of Termite Resistance

Wood blocks were placed about this depth above the residue layer and additional amounts of residues added to conceal the blocks, and the ground covered with top soil. The blocks (5 replications) were kept together according to species to aid identification of the specimens at the end of test. The places and positions of the test blocks were noted in the record book to easily know after test period.

After 16 weeks, the specimens were removed from the tested sites and cleaned up. The ground was unearthed, the blocks carefully retrieved, weighed immediately to determine the final wet weight and then oven dried. Determinations the moisture content of final block (% g/g), absolute mass loss (in mg) and percentage mass loss (% g/g) were carried out. Then these final mass of specimens were weighed after 48 hour at 60°C in oven by the same way of determination of initial mass.

The test blocks were also rated according to an arbitrary 0-5 visual scale as: 0 = sound, l = surface, 2 = light attack, 3 = moderate attack with bore holes, 4 = heavy/severe attack and 5 = completely destroyed. The grading by mass loss of specimen was corrected by visual observation.

On the basis of the percentage of wood eaten (weight loss in percent) by termites during the test period, the termite resistance of tested wood species were grouped into the following various resistance classes (P.K. SEN-SARMA, 1975).

Percentage of weight loss of tested wood	**Termite Resistance Class**
0-6	Very Resistant (Class I)
7-10	Resistant (Class II)
11-14	Moderately Resistant (Class III)
15-17	Poorly Resistant (Class IV+)
Above 17	Perishable (Class V-)

3.5. Determination the Chemical Composition

3.5.1. Extraction the tested wood species

The wood samples were chipped and extracted with 500ml of 95% ethanol at room temperature for two months. During percolation, the crude mixture was frequently shaken to achieve the maximum extraction. The extracts were filtered using Whatman number-1 filter paper. The combined ethanolic extract was evaporated and the extract were re-extracted with ethylacetate and concentrated.

3.5.2. Phytochemical Examination of the wood extracts

Phytochemicals are non-nutritive plant chemicals that have protective or disease preventive properties. They are secondary metabolites and include glycosides, alkaloids, carotenoids, terpenoids, saponins, coumarins and antraquinones. These chemicals can provide valuable sources of natural pesticides (Cowan 1999; Gibbons 2005; Verma and Verma 2006).

To know phytochemical of the crude extract of the test species, the crude extracts of the test wood samples were tested the following Phytochemical properties- (1) Test for flavonoid, (2) Test for Phenolic compound. (3)Test for Terpenes, (4) Test for Saponin.

Preliminary tests for phytochemical analysis of the tested extracts

Phytoconstituents	**Extract**	**Test**
Flavonoids	95% EtOH	Conc: HCl and Mg turnings
Phenolic compounds	Distilled water	1% K_3 Fe $(CN)_6$ and 1% $FeCl_3$ test 10% Lead acetate test
Terpenes	95% EtOH	acetic anhydride, chloroform and sulphuric acid
Saponins	Distilled water	Foam test

Test for Flavonoides

Shinoda Test was used. In a test tube containing 0.5 ml of the extract, 10 drops of dilute hydrochloric acid followed by a small piece of magnesium turnings were added. Formation of pink, reddish or brown color indicated the presence of Flavonoid.

Test for Phenolic compound

3 drops of a mixture of 1 ml of 1% $FeCl_3$ and 1 ml of K_3 Fe $(CN)_6$ were added into 1 to 2 ml of the extract. A green colour indicated the presence of gallotannins and brown colour indicates the presence of pseudotanins. To 1-2 ml of the extract, lead acetate was added. White precipitate indicates the presence of tannin and phenolic compound.

Test for Terpenes

Two drops of extracted solution was placed into the test tube. Then, three drops of acetic anhydride, four drops of chloroform ($CHCl_3$) and one drop of sulphuric acid were added in this test tube and shake for 30 minutes. Yellowish green colour indicate the presence of Terpenes.

Test for Saponins

2 grams of the dried powder samples, 5 ml of distilled water were added and shaken vigorously. If frothing in solution indicated the presence of saponin.

Figure 3.1.Determination of Termite Resistance

A= Sample preparation

B= Binding the test samples were bind with tape

Determination of Chemical Composition

Slicing the tested samples

Air-drying the sliced samples

Extraction with 95% Ethanol solution

Filtering the sample extract

sample extract

Concentrated sample extract

4. Results and Discussion

4.1. Moisture content of tested species

The average moisture content of tested species is shown in table 4.1. One of the most important parameters for conducting a termite laboratory test is ensuring an adequate supply of moisture. Termites are delicate insects and are very prone to desiccation if enough moisture is not maintained in their environment (Kofoid et al.1946). Too little water can cause desiccation in termites, but excessive moisture can also have adverse effects on termite foraging and survival.

In their natural environment, subterranean termites have many avenues to prevent desiccation or to maintain their desired level of moisture content. Subterranean termites build shelter or mud tubes made of mud and feces to maintain a humid environment while traveling across exposed areas. According to Forschler and Henderson (1995), when termites are subjected to large quantities of water they do not try to escape but enter into a “state of quiescence”. This indicates that if termites were subjected to a higher than normal moisture content, feeding rates could be affected and the termites may have been in a more relaxed state with the higher volumes of water. They indicated that the greatest weight loss occurred in the lowest moisture volume test. Therefore, the moisture content of the test blocks was maintained at nearly air dry state.

Table 4.1: Moisture content and leight Loss (%) of tested species

Sr. No	Species	Scientific Name	M.C (%)	Wt. Loss (%)	Vissual rating
1	Pyinkado	*Xilia xylocarpa* Roxb.	11.211	0.573	0
2	Thingan	*Hopea odorata* Roxb.	11.501	1.478	0
3	Kyun	*Tectona grandis* Linn. f.	11.464	1.623	0
4	Thitya	*Shorea oblongifolia* Obtuse Wall	10.575	2.322	0
5	Padauk	*Pterocarpus macrocarpus* Kurz	11.507	4.374	0
6	Ingyin	*Shorea siamensis* (Kurz) Miq	10.694	6.573	0
7	Yinma	*Chukrasia tabularis* A. Juss	14.941	4.398	0
8	Gyo	*Schleichera oleosa* (Lour) Oken	10.914	4.446	0
9	Panga	*Terminalia chebula* Retz	10.675	4.661	0
10	Thitpayaung	*Neonauclea excels* Blume	12.546	5.093	0
11	Taukkyan	*Terminalia tomentosa* (Wight &Arn)	11.657	5.128	0
12	Thitkha	*Pentace burmanica* Kurz	10.617	5.775	0
13	Yemane	*Gmelina arborea* Roxb	12.813	7.480	0
14	Taungpeinne	*Artocarpus chaplasha* Roxb	11.138	9.142	0
15	Hnaw	*Adina cordifolia* Hook.f	11.036	10.169	1
16	Leza	*Lagerstrormia tomentosa* Presl	10.796	13.997	1

4.2. Termite resistance of tested species

The mean percent weight losses of tested species were also shown in table 4.1. According to this table it can be found that among the tested species, the above sixteen species were very resistant to termite attack. They have no any surface damages and can be marked as sound (No Attack) according to visual rating.

On the basis of the percentage weight loss of wood (eaten by termites) during the test period, it can be said that the termite resistance of 11 species of tested wood were very resistant (Class I), because of having the weight losses less than 6% and 4 species were resistant to termite Class II.

According to Table (4.2), it can be found that, average weight loss for Pyinkado (*Xilia xylocarpa)* is the lowest among the test species and there is no surface damage after sixteen week exposure. Therefore, it can be concluded that Pyinkado is very resistant to termite attack.

The weight loss percent of Thingan (*Hopea odorata)* was 1.478% and it can be compare with Teak (*Tectona grandis)* which has the weight loss of 1.623%. The weight loss percent of Thitya (*Shorea oblongifolia)* was 2.322% and it also very resistant to termite attack. It can also be seen that the mean weight losses of Padauk *(Pterocarpus macrocarpus),* Yinma *(Chukrasia tabularis),* Gyo *(Schleichera oleosa),* Panga *(Terminalia chebula)* are nearly the same and the range are between 4.374% and 4.661%. These species are also resistant to termite attack. According to table, it can be seen that, the weight loss% of Thitpayaung (*Neonauclea excelsa*), Taukkyan(*Terminalia tomentosa*) and Thitkha (*Pentacebur manica*) were found to be 5.093, 5.128 and 5.775 and they may be more resistant than Ingyin (*Shorea siamensis)* which has the weight loss of 6.573%.

The weight losses of Yemane(*Gmelina arborea*), Taungpeinne(*Artocarpus calophyla*) and Hnaw (*Adina cordifolia*) were found to be 7.48%, 9.142%, and 10.169% respectively. It can also be said that these species are resistant to termite attack. Leza *(Lagerstrormia tomentosa)* has the weight loss of 13.997% and it is moderately resistant to termite attack.

According to the finding of P.K. SEN-SARMA (1975), Pyinkado has the weight loss of 4.23% to 4.95% and grouped as Class I. In the case of Hnaw (*Adina cordifolia*), the mean weight losses was 14.44% and it ranged between 10.99- 19.66 marked as Class III. The result may be different according to the test block size, grain direction, wood density, and termite species.

4.3. Correlation between termite resistance and specific gravity and density.

Esenther (1977) stated that natural resistance of wood to termite attack seems to be correlated with wood species that have a higher **specific gravity**. J. M. Owoyemi et. al, tested the resistance of some indigenous tree species to Termite Attack in Nigeria and they reported that wood in the high density class had a better resistance to attack by termites compared with low density wood.

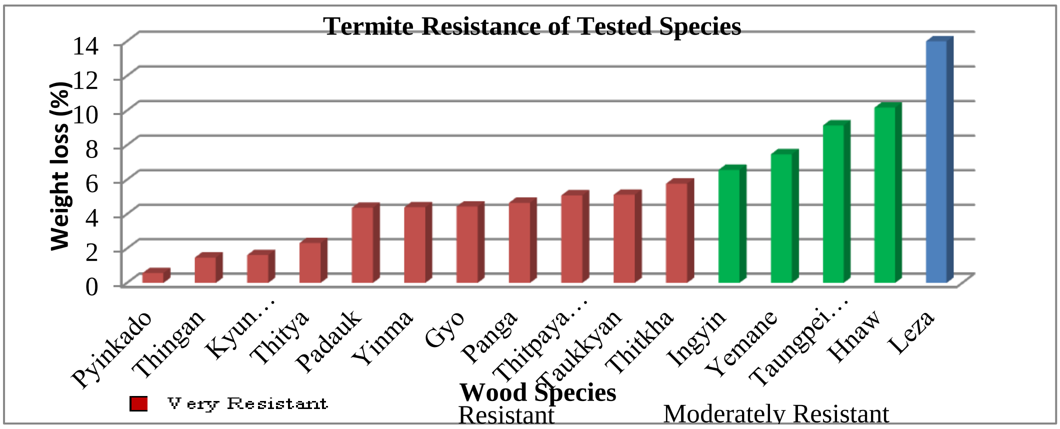

Figure 4.1. Termite Resistance of Tested Species

The resistance on subterranean termites of tested wood samples was shown in Table (4.2). The weight losses of test wood blocks after sixteen week exposure against termites, specific gravity (Sp. Gr.), Density at Air dry condition and visual rating of test samples are presented in this table. Specific gravity values and Density at Air dry values from the table were taken from Cho Cho Win and Prof. Win Kyi-1 (2008).

Table 4.2. Sp. gr, density at air dry and weight loss (%) of tested species

Sr. No.	Species	Sp. Gr.	Density at Air Dry (Kg/m^3)		Weight Loss (%)
			M.C (%)	Density	
1	Pyinkado	0.779	10.3	897	0.573
2	Thingan	0.637	12.1	753	1.478
3	Teak	0.598	13.9	673	1.623
4	Thitya	0.858	10.6	1026	2.322
5	Padauk	0.752	12.0	892	4.374
6	Ingyin	0.781	13.4	929	6.573
7	Yinma	0.938	12.0	946	4.398
8	Gyo	0.779	12.0	1157	4.446
9	Panga	0.720	12.0	960	4.661
10	Thitpayaung	0.815	12.0	907	5.093
11	Taukkyan	0.558	12.0	992	5.128
12	Thitkha	0.779	13.9	657	5.775
13	Yemane	0.435	12.0	551	7.480
14	Taungpeinne	0.601	12.0	506	9.142
15	Hnaw	0.469	12.0	713	10.169
16	Leza	0.583	12.0	679	13.997

Figure 4.2 showed that there is no correlation between termite attack and basic specific gravity. In this graph, it can be seen that although the sp.gr of Pyinkado, Gyo and Thit-kha have the same values, 0.779, their weight losses against termite were 0.578, 4.446 and 5.775 respectively.

Similarly, Figure 4.3 showed that there is no correlation between termite attack and density. Therefore, it can be reported that termite resistance of wood is not related to not only specific gravity but also density. Therefore, it might be correlative with extractives in it.

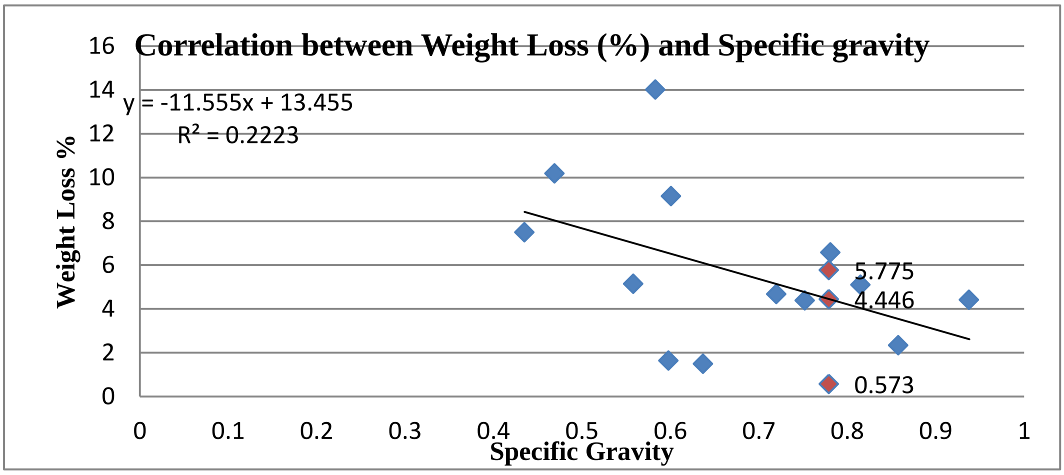

Figure 4.2. Correlation between Sp. Gr and Termite Resistant

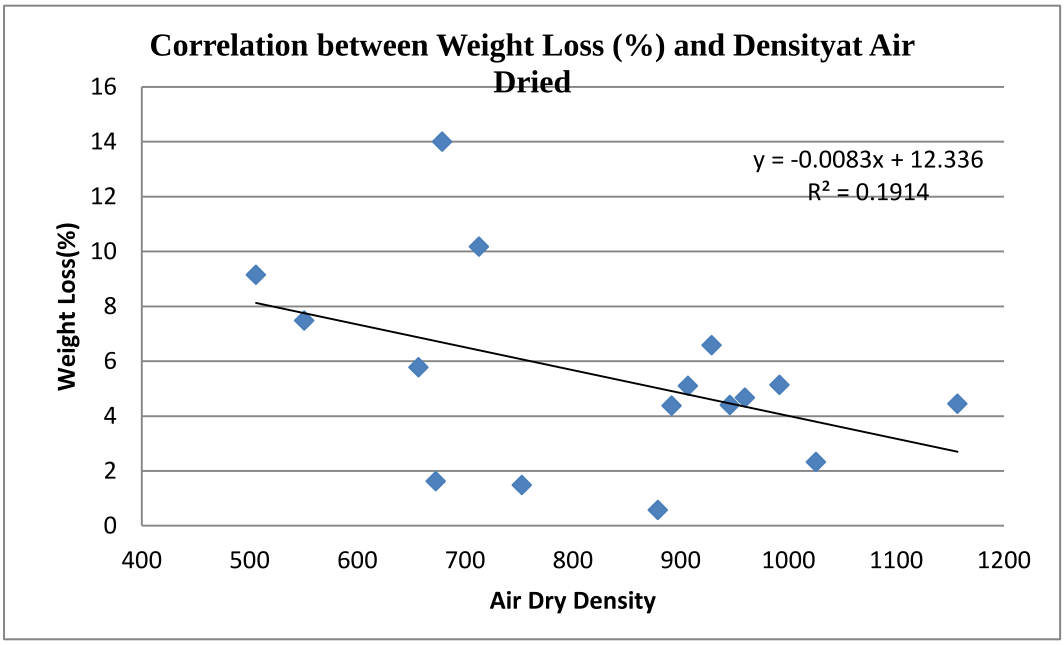

Figure 4.3. Correlation between Density and Termite Resistant

4.4. Determination the Chemical Composition

Preliminary Phytochemical Examination

The preliminary phytochemical studies were performed for testing the different phyto-constituents (mainly on flavonoid, Phenolic compound) present in the ethanolic extract of the following ten species.

Table 4.3. Results of Phytochemical Screening of the tested Species

Sr. No.	Species	Flavonoid	Phenolic compound	Terpene	Saponin
1	Pyinkado	+	+	+	+
2	Thingan	+	+	+	+
3	Kyun(Teak)	+	+	+	+
4	Thitya	+	+	+	+
5	Padauk	+	+	+	+
6	Ingyin	+	+	+	+
7	Thitkha	+	+	+	+
8	Gyo	+	+	+	+
9	Panga	+	+	+	+
10	Taukkyan	+	+	+	+

According to this table, it can be seen that preliminary phytochemical screening of the ethanolic extract of above mentioned species have Flavonoid, Phenolic compound, Terpene and Saponin. However, there were many compounds under the flavonoid. Therefore, the compound contained in specific wood species need to be tested. Some examples for flavonoid are as follow:-

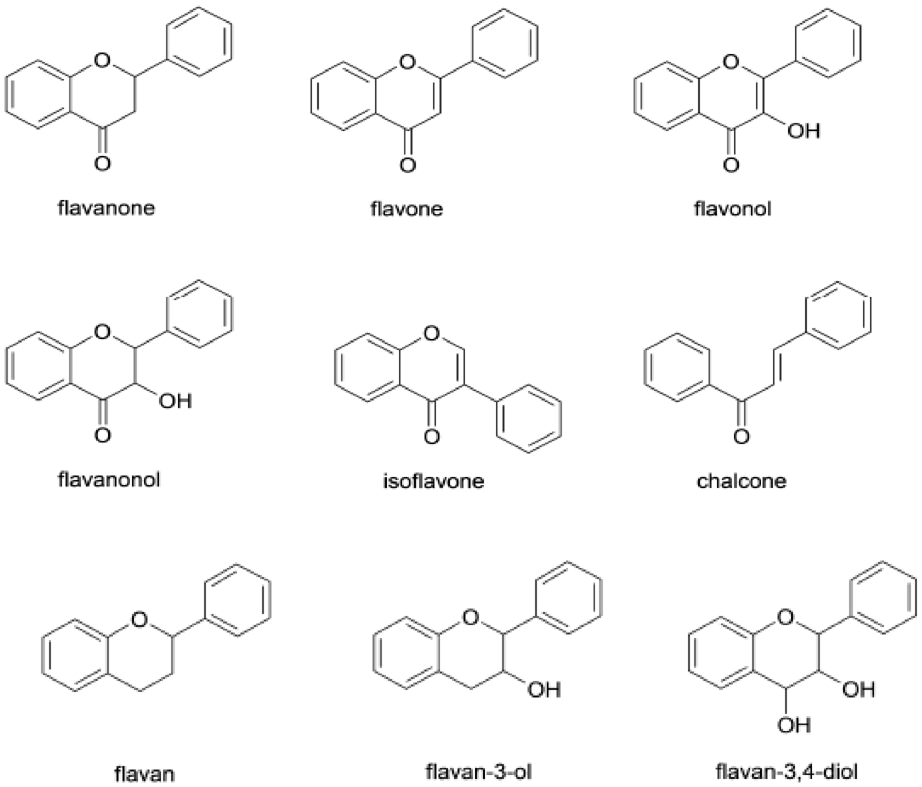

Figure 4.4. Some flavonoid compounds and structures

The following statements were agreed with the research finding.

Preliminary phytochemical screening of the ethanolic extract of the *Terminalia tomentosa* stem bark revealed the presence of carbohydrates, flavonoids, triterpenoids, steroids, tannins & saponins.

The antifeedant activities of pterocarpans isolated from the heartwood of *Pterocarpus macrocarpus* Kruz. (Leguminosae) were evaluated against the subterranean termite, *Reticulitermes speratus* Kolbe (Isoptera: Rhinotermitidae). Three isolated pterocarpans were used and all pterocarpans showed antifeedant activity against *R. speratus* (Morimoto et al, 2006).

From the heartwood of *Dalbergia spp* (Leguminosae) were isolated and identified as active against termites and fungi, the neoflavonoids, latifolin, dalbergiphenol, and 4-methoxydalbergione.

The extract of *Terminalia chebula* Retz has a number of chemical constituents and possess various pleiotropic effects such as antioxidant, antimicrobial activity (Aparna et al, 2014). Flavonol glycosides, triterpenoids, coumarin conjugated with gallic acids called chebulin as well as other phenolic compounds were also isolated in T. chebula.

Previously, the chemical constituents of the wood of *X. xylocarpa* have been reported some flavan-3-ols including monomer, dimer, and trimer of epiafzelechin.

5. Conclusion and Recommendation

The results of the study indicate that:-

(1) Sixteen native wood species are resistant to termite attack. Among them, Yinma, Gyo, Panga, Thitpayaung, Taukkyant, Thitkha, Yemane, Taungpeinne, Hnaw and Leza are lesser used species in Myanmar.
(2) Termite resistance of wood is not related to not only specific gravity but also density.
(3) In the sixteen species contain Flavonoids, Terpene, saponin and phenolic compound. It can be used as wood preservatives for termite control (termiticide).

Evaluation of natural termite resistance in native and tropical species is becoming increasingly important in the wood industry sector; because there has been a greater focus in reduce harvesting the wood and conservation the environment. Wood extractives play a major role in the susceptibility or durability of wood against wood decay organisms. The attack of these organisms in general can be prevented with synthetic organic and inorganic preservatives; however, such products are very harmful to human health and the environment. Most of the tested species have termiticidal extractives, such as Flavonoids and Quinones, these species could be used as potential for wood preservative producing wood species.

In this study, we conducted **preliminary investigation** on the antitermite activity of some wood extracts. We have to study to identify potential anti-termite compound, active ingredients and fractionated to obtain and pure compounds employed to test and to study an effective repellent and toxic formulation to kill field termites both in laboratory and field conditions.

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Appendix 1. Economic losses attributable activities

Country	Crop losses (%)	Building damage (%)	Economic losses/annum (Million US $)	Reference/Source
Australia	–	–	>95.24	(UNEP 2000)
Brazil	–	42.7	–	(Milano and Fontes 2002)
China	–	80–90	248.68–292.79	(Zhong and Liug 2002)
Europe	–	–	313	(UNEP 2000)
India	15–25 (Maize crop)	–	35.12	(Joshi et al. 2005)
Japan	–	–	800	(UNEP 2000)
Malaysia	–	70 – Residential 20 – Industrial 10 – Commercial	8–10	(Lee 2002)
Southern Africa	3–100	–	–	(Mitchell 2002)
Spain	–	53.2	–	(Gaju et al. 2002)
United States	–	–	>1000	(UNEP 2000)

Appendix III. Some effects on essential oils of various plants on termites (Verma et al.2009)

Plant	Part	Active component	Activity
Thujopsis dolabrata Siebold & Zucc.	Wood	b-Thujaplicin and carvacrol	Toxic
Chamaecyparis pisifera (Siebold & Zucc.) Endl.	Wood	Chamaecynone and isochamaecynone	Toxic
Cryptomeria japonica D.Don	Wood	b-Eudesmol and cedrol	Toxic
Azadirachta indica A.Juss.	Seed	Limonoids	Antifeedant
Chamaecyparis obtusa Siebold & Zucc.	Wood	Monoterpene, sesquiterpene, and sesquiterpene alcohol	Toxic
Thujopsis dolabrata Siebold & Zucc.	Wood	Thujopsene	Toxic
Taiwania cryptomerioides Hayata	Wood	Cedrol and a-cadinol	Toxic
Vetiveria zizanioides Nash	Root	Nootkatone (a sesquiterpene alcohol) and cedrene	Arrestants, feeding deterrent, repellent and toxic
Cinnamomum osmophloeum Kaneh.	Leaf	Cinnamaldehyde	Toxic
Tagetes erecta L.	Leaf	(Z)-ocimene	Mortality
Lepidium meyenii Walp.	Leaf	Benzylthiocynate, 3-methoxyphenylacetonitrile and b-ionone	Feeding deterrent
Melaleuca gelam and Melaleuca cajuputi Powell	Leaves and twigs	Elemene, g-terpinene and terpinolene, Monoterpenes, sesquiterpenes, hydrocarbons and a diterpene	Toxic
Calocedrus formosana (Florin) Florin	Leaf	T-muurolol	Toxic
Allium sativum **L.** and *Eugenia caryophyllata* Thunb.	Bud	Diallyl trisulphide, Diallyl disulphide, eugenol, Diallyl sulfide and b-caryophyllene	Toxic
Callitris glaucophylla Joy Thomps. & L.A.S.Johnson	Wood	Guaiol, a-eudesmol, and b-eudesmol, citronellic acid and geranic acid	Repellent

Appendix II. Some effects on plant extracts on termites (Verma et al. 2009)

PLANT	PART	ACTIVE COMPONENT	ACTIVITY
Adina racemosa Miq.	Bark	Benzoic acid	Toxic
Aframomum melegueta K.Schum.	Seed	Gingerol [5-hydroxy-L-(4-hydroxy- 3-methoxyphenyl)decan-3-one] and shogaol [1-(4-hydroxy-3-methoxyphenyl)dec-5-en-3-one]	Antifeedant
Detarium microcarpum Guill. & Perr.	Leaves	Clerodane diterpenes, 3,13E-clerodien-15-oic acid, 4(18),13E-clerodien-15-oic acid, 18-oxo-3,13E-clerodien-15-oic acid and 2-oxo-3,13E-clerodien-15-oic acid	Antifeedant
Xylopia aethiopica A.Rich.	Fruits and seeds	Diterpenes and amides	Antifeedant
Moneses uniflora A.Gray	Aerial parts	Naphthoquinones, 2, 7-dimethyl-1,4-naphthoquinone and 3-hydroxy-2,7-dimethyl-1,4-naphthoquinone	Toxic
Flourensia cernua DC.	Leaves	Monoterpenes and sesquiterpenes	Toxic
Diospyros sylvatica Roxb.	Root	2-methyl-anthraquinone, plumbagin, diosindigo, isodiospyrin and microphyllone (quinones)	Repellant and toxic

PLANT	ACTIVE COMPONENT	EFFECT ON TERMITES
Kalopanax septemlobus Koidz.	Saponins	Toxic
Ternstroemia japonica Thunb.	Barrigenol glycoside (saponin)	Toxic
Podocarpus macrophyllus D.Don	Inumakilactone (bisnorterpenoid)	Toxic
Callistris species	L-citronellic acid, D-citronellic acid, L-dihydrocitronellic acid, D-dihydrocitronellic acid, geranic acid, tetrahydrogeranic acid, caprylic acid, pelargonic acid and enanthic acid	Lethal
Pinus lambertiana Douglas	Fatty acids and alpha halogenated compounds	Feeding deterrent
Sciadopitys verticillata Siebold & Zucc.	Isoeugenol mono-Me ether and cedrol	Toxic
Chamaecyparis obtusa Siebold & Zucc.	Diterpenes, T-muurolol and a-cadinol	Toxic
Chamaecyparis lawsoniana (A. Murray) Parl.	a´ -terpineol and 3sesquiterpene alcs., T-cadinol, torreyol (a¨-cadinol), and a´ -cadinol	Toxic
Pometia pinnata J.R.Forst. & G.Forst.	Saponins	Toxic
Catalpa bignonioides Walter	Catalponol and catalpalactone	Toxic