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MANAGEMENT OF TERMITE POPULATION BY USING PLANT NATURAL PRODUCTS MAINLY LATEX AND ITS COMPONENTS FROM FAMILY APOCYNACEAE

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ABSTRACT

The present review article, explain the use of plant latexes and other plant natural products for control of termites. Termites are polyphagous, highly destructive pests which cause significant loss to agricultural crops, food, fibres, wood materials and other house hold materials. However, for termite control different synthetic highly toxic chemical insecticides were used. But these toxic chemicals were proven very harmful to microbiota of soil, invertebrates and vertebrates. Besides targeting insects, these synthetic chemicals also kill non-targeted organisms. These toxic chemicals enter into the food chains and imposing adverse effects on various organisms. These chemicals after metabolism move further inside biological system and show bio-accumulation. These persist for a much larger time in the form of bound residues which were proved harmful to parental components. Termite control by plant lattices is eco-friendly and environmentally safe. Latexes are secreted by many flowering plant families. In this article, the latex and other plant natural products have been suggested for termite control. They inhibit metabolism in termites and kill them due to anti-feedant, repellent and toxic action. This article also explains cultural, behavioral, microbial, genetical and biological control of termites to to cut down termite menace in an eco-friendly manner. This article also suggests production of plant based natural formulations for termite control to save the ecosystem and its biotic components.

KEYWORDS: Plant natural products**,** plant latex**,** termites, apocynaceae**,** subterranean termites, *Coptotermes formosanus*, *Reticulitermes flavipes*, *Odontotermes*, *Calotripis procera.*

1. INTRODUCTION

Termites are polyphagous detritus feeders that belong to order Isoptera and class insecta. They are the most successful and highly invasive insects on the earth. These are voracious feeders show morphological variations and live eusocially within the colony. They feed mainly on cellulose containing materials like wood, household furniture and other wooden structures. Termites found worldwide in all climatic regions except few colder regions. These are major pests and are causing great losses to field crops, damage valuable structure in buildings, bridges, dams, roads or by damaging crops, forests tree. It must be recognized at the outset that termites are a part of the natural ecosystem of the world. These are major pests and are causing great losses to field crops, damage valuable structure in buildings, bridges, dams, roads or by damaging crops, forests tree (Photograph 1e-1f). It must be recognized at the outset that termites are a part of the natural ecosystem of the world.

Termites attack a variety of crops at any stage of development and cause great loss in agriculture. A particular crop infested by some particular termite genera because different species of termites live in a habitat with variable amount of moisture. Termite infestation reduces crop yield up to a threshold level (Ahmad et al., 2021). Termites usually attack on crops; they may usually feed on plant roots, aerial part of the plant and make several injuries. They cause detectable damage that result in loss of yield quantity or quality. Wood-feeding termites digest and degrade lignin biopolymers and release glucose and other fermentable sugars from recalcitrant plant cell wall carbohydrates, including cellulose and hemicelluloses with the help of gut symbionts (Scully et al., 2013). Thus, termites cause great economy loss that approximately estimated to approach $30 billion worldwide (Culliney and Grace 2000).

There are 3,106 species of termites described while 500-1000 species still left to describe worldwide. In India, total 337 species are known till now. Among them, 35 reported to responsible for significant damage in agricultural crops and buildings. The major damaging species of termites in India are *Odontotermes*, *Coptotermes*, *Heterotermes*, *Microtermes*, *Microcerotermes* and *Trinervitermes*. Among them *Odontotermes* is responsible for major loss infesting crops and building structures (Paul et al., 2018). Termites are soft-bodies insects, so they do not inhabit a cool environment. The different species of termites inhabit wood, crops and furniture with varying moisture content. Ecologically three types of termites found all over the world except Antarctica. The main types of termites are:

I. Subterranean termites

Subterranean termites are found all around the world except Alaska. These termites live either underground colonies or above ground secluded area. Subterranean termites are a major structural pest causing a tremendous amount of damage to homes, commercial buildings and other historical structures. They consume valuable books, documents and photograph (Zorzenon et al., 2015). Subterranean termites are most successful among termites; their success can be attributed to their cooperative behavior. They are eusocial termites, as well developed division of labor are found among the members of the colony and each caste performs a specific job to benefit the whole colony (Sun et al., 2020).

II. Drywood termites

Drywood termites infest dry wood. This species of termites established their colony in woodroof or wooden support and they do not need contact with soil because they do not require much moisture like other species of termites. Since they have the ability to decompose wood with low moisture content, they may attack every kind of dead and dried wooden structure such as timber, furniture and other wooden structures. But their colony may also be found in wooden things situated near a water source (Cosme et al., 2017). This species, mostly infest the wooden things in the houses, dried tree and other wooden structures. They are found only some part of the world. Their distribution restricted to the southern tier states, from North Carolina through the Gulf Coast and in the coastal areas of California.

III. Dampwood termites

Dampwood termites infest wood or wooden structures of varying level of decay and moisture content. The size of these termites is longer than the other species of termites. They do not infest wooden household structures because of low moisture contents. Their distribution also restricted to only some part of the world such as in the Pacific coastal and southern Florida.

Termites are belonging to infraorder Isoptera. Once they are classified in a separate order, but the studies in 1993 indicate that they are more similar to wood-cockroaches on the basis of their gut symbionts. DNA sequencing of 16s RNA in 2008 also confirmed that termites more related to wood-cockroach. Thus, it was concluded that termites are evolved from cockroaches during Jurassic or Triassic period. Now, termites are classified at the taxonomic rank order Isoptera within the cockroaches. There are 3106 species of termites described while 500-1000 species still left to describe. The higher classification of those species splits into nine families. All family members are fully eusocial except some drywood termites (Kalotermitidae) which may not have functionally active workers.

A. Seasonal infestation

Subterranean termites are major destructive pest worldwide. They use plant litter present on the soil or ground. They feed on the wood structures for years without being detected. The Indian white termite, *Odontotermes obesus* (Rambur) (Isoptera: Odontotermitidae), is highly destructive polyphagous insect pest, lives in huge mounds, and feeds on cellulose material and almost anything which contains carbohydrate. It causes economic damage to commercial wood, fibers, cellulose, sheets, papers, clothes, woolens and mats, and woody building material and infests green standing foliages, cereals stored in godowns. Termites invade crops in agriculture field and garden plants and saplings (Photograph 1e-1f). In winter they avoid cold by hiding inside the plant litter, mud holes or in the underground tunnels of termitarium. In the spring season, as the temperatures warm up, mature termite colonies begin to send winged reproductives in search of locations to establish new nests. These winged reproductives, move out as swarmers and try to establish colonies before summer season. They can swarm anytime during the warm months. Due to favorable climatic conditions colony size and number gets increase and large numbers of workers and soldiers come out invade crop or leafy vegetation wood, and other items and materials for feeding. For this reason, it is important to move wood sources (especially damp wood) away from the foundation perimeter.

In dry summer season, subterranean termites become active and worker termites form mud tubes or shelter tubes to get from the ground to the wood man-made structures. Forest termites do make plastering and surface the humidified mud on tree trunks (Photograph 1e-1f). All these structures they eate hiding them in in dark places. Workers do not like light. Workers can eate mud tubes any, and make termitariums inside feeding or foraging areas or in their periphery. Invasion by colony members depend on seasonality when colony members raid the crop field in large numbers. In the fall or post summer season, termite activity get slow down, and they try to shift in, warm area ground the soil or underneath a man-made structure. It is important for termites to feed and protect themselves all year long. Subterranean termites don't like the light. This aversion to light will have these insects feeding all the way up to rub the soil on the walls, make holes in wood and remain inside without making noise.

Climate change and its impact on termite control

The seasonal changes affect the foraging activity and wood consumption of the Formosan subterranean termite, *Coptotermes formosanus* Shiraki (Isoptera: Rhinotermitidae). Wood consumption is the lowest in December, February, and March. Prolonged periods of cold weather, with average soil temperatures below 15 degrees C, caused a significant number of termites to abandon underground (Cornelius and Osbrink 2011). Diet and length of time affect the intercolonial agonism among Formosan subterranean termite, *Coptotermes formosanus* Shiraki colonies. Aggressive behavior also decreased over time according to the diet and length of time. Any changes in environmental factors affect intercolonial agonism (Cornelius and Osbrink 2009).

Fungus-growing termites increased decomposition rates strongest (+123%) under the most water-limited conditions, making overall decomposition rates mostly independent of rainfall. Fungus-growing termites are of special importance in decoupling decomposition rates from spatiotemporal variability in rainfall due to the buffered environment they eate within their extended phenotype (mounds), that allows decomposition to continue when abiotic conditions outside are less favorable (Veldhuis et al., 2017). Numbers of workers, soldiers, and soldier/worker ratio are also significantly affected by month. The numbers of nymphs in a colony are highly variable within the season mainly from March onwards (Cornelius et al, 2015).

2. Termite control

So far studies have been done on pest control, different synthetic toxic chemical insecticides have been used for termite control were. Besides targeting insects, these synthetic chemicals also kill non-targeted organisms. These toxic chemicals enter into the food chains and imposing adverse effects on various organisms. These toxic chemicals were proven very harmful to microbiota of soil, invertebrates and vertebrates. These chemicals after metabolism move further inside biological system and show bio-accumulation. These persist for much larger time in form of bound residues which were proved harmful to parental components. The persistent use of synthetic termiticides resulted in serious environmental problems; hence there is a need to search for plant-derived compounds as an alternative for termite control (Xie et al., 2013). Green pest management is an environmental-friendly pest management that helps to control pests and reduces harmful use of pesticides. Green pest management is a relatively new concept. It includes sanitation, management, biological control, least toxic chemical pesticides and minimum use of chemicals and avoids killing of non-target species by spraying in target locations (Srivani Maddala et al., 2019).

A. Termite control using plant natural product

So many natural products are used for termite control. Most of them are plant secondary metabolites that are used to control infestations and physical damage caused by termites. Plants produce specialized metabolites or chemicals for their defense against a diverse group of organisms (Livshultz et al., 2018). Plants synthesize diverse chemical metabolites in response to insect or pathogen attack and protection from predators, mainly latex producing plants (Ernst M et al., 2019). The chief secondary metabolite of the families Apocynaceae, Loganiaceae and Rubiaceae are monoterpenoid indole alkaloids (Szabó 2001 et al., 2001). Few of alkaloid glycosides display antitermitic (Araya et al., 2012). Plant alkaloids target insect pests effectively and efficiently (Runguphan et al., 2009).

Terpene indole alkaloids are plant natural products with diverse structures and biological activities. The roots of *Cynanchum stauntonii* 18:20-triepoxy-5α:9α-peroxy-14, 15-secopregnane-6,8(14)-diene named as stauntogenin G as the aglycones which show anti-termite activity (Deng et al., 2017). The monoterpenoid indole alkaloids produced by *Ervatamia hainanensis* also display antitermite efficacy (Zhang et al., 2015). Similarly, plant-derived monoterpene indole alkaloids, which include vinblastine, quinine, and strychnine, originate from a single biosynthetic intermediate, strictosidine aglycone are anti-termite in nature (Stavrinides et al., 2015). In plant-derived ajmalan alkaloid pathways, are also protective against termite infestation (Dang et al., 2017). Cardenolides are natural product synthesized by plants in response to increase toxicity (Rasmann and Agrawal 2011).

Natural products from the various part of *Isodon rugosus* plant contain various flavonoids, which have the potential to kill termites. The anti-termitic activities of flavonoids depend on the compounds which are used during fractionation (Zeb et al., 2017). Chloroform extract of the roots of *Diospyros sylvatica* contain various natural products including 2-methyl-anthraquinone, plumbagin, diosindigo, diospyrin, isodiospyrin and microphyllone. Among them all have capability to kill the termite except diospyrin (Ganapaty et al., 2004). Chromene analogs derived from a natural-product-based chromene amide isolated from *Amyris texana* is used to control *C. formosanus*. These compounds exhibited significantly higher mortalities in termites (Meepagala et al., 2011). Secondary metabolites from *Alpinia galanga* (L.) locally known as lengkuas show potency to repel two species of termites, *Coptotermes gestroi* (Wasmann) and *Coptotermes curvignathus* (Holmgren) (Isoptera: Rhinotermitidae). The main repellent compound is 1,8-cineol. It shows repellency 250 ppm of 1,8-cineol caused 50.00 ± 4.47% for *C. gestroi*, whereas for *C. curvignathus* 750 ppm of 1,8-cineol is needed to cause similar repellent activity (Abdullah et al., 2015). Natural products vulgarone B, apiol and cnicin exhibited significantly higher mortalities in *Coptotermes formosanus*. These compounds are present at high levels in plant sources and also possess other biological activities such as phytotoxic and antifungal properties (Meepagala Osbrink et al., 2006).

Most natural products (NPs) are neuroactive and affect central nervous system (CNS). Bio-organic compounds show high brain penetration potential in complex mixtures. The extracts prepared from *Tanacetum parthenium*, *Vinca major*, *Salvia officinalis*, and *Corydalis cava* contain different types of chemical diversity and complexity that are used against local termite (Könczöl et al., 2013). Thus, natural compounds can be used for potential control of several important agricultural and household structural pests including termites. Among the various natural plant products, cycasin caused significant mortality in termites (Schrader et al., 2010).

B. Plant extract in termite control

Since long times extract of various plants is used in insect pest management. The extract of various plants acts as repellent, anti-feedent and even toxic to the insects (Bernard et al., 2020). Generally, plant extracts act as a repelling agent for insect and it is due to the presence of various ingredients in the extract. Plant-based repellents have been applied for generations in traditional practice as a protective agent against insects (Asadollahi et al., 2019). The extract of the leaves, roots, peels of the fruits and other part of the various plant of family apocynaceae have potential to control termites. The potential activity of extract depends on the chemical which is used in extract. The plant extract formulation affects the orientation and survival of subterranean termites (Bläske and Hertel 2001).

The linseed oil with the wood extract of *Tectona grandis*, *Dalbergia sissoo*, *Cedrus deodara*, and *Pinus roxburghii* show excellent anti-termitic activity and could be used actively as protectants of non-durable wood species against the termite, *Heterotermes indicola*. The mixture of extract with linseed oil increase synergistic effect (Hassan et al., 2020). Similarly, heartwood extract from white mulberry (*Morus alba* L.) (Rosales: Moraceae) cause excellent mortality in termites at 10 mg/ml and the LC50 of the heartwood extract is 1.71 mg/ml against *Reticulitermes flavipes* (Kollar) (Blattodea: Rhinotermitidae) (Hassan et al., 2018).

The ethanolic extract of leaf from *Cunninghamia konishii* show excellent antitermitic activities. Among the four fractions of wood ethanolic extract, the hexane-soluble fraction shows the strongest antitermitic activities. In addition, β-elemol and α-cadinol show excellent inhibitory action against *C. formosanus* (Cheng et al., 2014). Chloroform extract of dry *Lantana camara* 'Mozelle' show anti-feedent and toxic effect against the eastern subterranean termite *Reticulitermes flavipes* (Kollar). The anti-feedent and toxic effect of the latex is concentration dependent as it cause 90% mortality and 78% reduction in feeding at 0.212 concentration while 52% mortality and 40% reduction in feeding occurred at 0.106 mg/cm^2 (Yuan and Hu 2012). In the chloroform extract of the roots of *Diospyros sylvatica*, six quinones are identified as 2-methyl-anthraquinone, plumbagin, diosindigo, diospyrin, isodiospyrin and microphyllone. These compounds affect the the orientation and survival of the subterranean termite, *Odontotermes obesus*. Quinones show higher repellent activity against termites and are also proven toxic at higher concentration (Ganapaty et al., 2004).

From *Juniperus procera* cedrol, a tertiary tricyclic alcohol, is isolated that showed anti-termitic activities such as anti-feedent, toxic and repellent (Kinyanjui et al, 2000). The ude extracts as well as different fractions of *C. anisata* show excellent termicidal activity against various termite species. The main compounds reported are marins, carbazole alkaloids and limonoids (Mukandiwa et al., 2016).

From *Echinops* spp. eight thiophenes have been isolated and each of them possesses varying degrees of termiticidal activity. 2, 2':5', 2''-Terthiophene and 5'-(3-buten-1-ynyl)-2, 2'-bithiophene demonstrated 100% mortality against *C. formosanus* at 1 and 2 wt% concentrations respectively. Among various thiophenes two show strongest termicidal activities (Fokialakis et al., 2006). Plant extract from *Pyllanthus niruri*, *Azadirachta indica*, *Leucaena leucocephala* and *Andrographis paniculata* affects the tunneling activity and the behaviour of two subterranean termites, *Globitermes sulphurues* and *Coptotermes gestroi*. The plants extracted with different solvents exhibit variable activity against termites. Plants extracted with methanol demonstrated strong repellent properties with 0 tunneling activity on the treated sand and low survivorship of both termites (Bakaruddin and Majid 2019).

C. Termite control by Essential oils

Essential oils are liquid extracts from aromatic plants which are extracted from various plant parts for and have multiple uses. Essential oils are derived from plants and considered as the most efficient alternative in controlling insect pests like termites (Alavijeh et al., 2014). EOs is mixtures of secondary metabolites or natural organic compounds obtained from plants. These contain mixed functional groups and lipophilic in nature and are highly volatile at a very low temperature. More than 200 constituents are present in essentials oils obtained from different plants (Aziz et al., 2018). The essential oils used since long times for their bactericidal, virucidal, fungicidal, antiparasitical and insecticidal properties. Now days it uses in pharmaceutical, sanitary, cosmetic, agricultural and food industries increases (Bakkali et al 2008).

The essential oils show high repellent and antifeedent activity against Formosan subterranean termite, *Coptotermes formosanus* Shiraki. The anti-termite potential of essential oils mainly depends upon the plant material, exposure time, and concentration (Park and Shin 2005). The essential oil of *L. sidoides* and *thymol* are more toxic to *C. brevis* pseudergates when applied by contact (LD50 = 9.33 and 8.20µgmg-1, respectively) and by fumigation (LC50 = 9.10 and 23.6µLL-1, respectively) (Santos et al., 2017). Chinese cedar (*Cryptomeria fortunei* Hooibrenk) shows antitermitic activity against *Reticulitermes chinensis*. In the essential oil of Chinese cedar, α-terpineol is responsible for the antitermitic property and the lethal concentration (LC50) value of leaf essential oil is 2.80 mg/mL. (Xie et al., 2013). Wood and leaf essential oils from *Cunninghamia konishii Hayata* show excellent antitermitic activities. Among various extract obtained using different solvent, the hexane-soluble fraction show the strongest antitermitic activities against Formosan subterranean termite, *Coptotermes formosanus* (Isoptera: Rhinotermitidae). The anti-termitic property of extract is due to the presence of β-elemol and α-cadinol in extract (Cheng et al., 2014).

The essential oils of vetiver grass, cassia leaf, clove bud, cedarwood, *Eucalyptus globules*, *Eucalyptus citrodora*, lemongrass and geranium) show antitermite properties against the Formosan subterranean termite, *Coptotermes formosanus* Shiraki. Vetiver oil proved the most effective repellent because of its long-lasting activity. Clove bud was the most toxic, killing 100% of termites in 2 days at 50 micrograms/cm2. Vetiver oil decreased termite tunneling activity at concentrations as low as 5 micrograms/g sand (Zhu et al., 2001). Similarly, vetiver oil and its components are also capable to disrupt food recruitment by termites. Sand treated with vetiver oil or nootkatone disrupted termite tunneling behavior. Wood consumption and termite survival are significantly lower compared with cedrene-treated or untreated sand treatments. Sand treated with vetiver oil or nootkatone at 100 microg/g substrate are effective barriers to termites (Maistrello et al., 2001). Oil from citrus peel, referred as orange oil extract (OOE), contains -92% d-limonene, and it is generally known to be toxic to the Formosan subterranean termite, *Coptotermes formosanus* Shiraki (Isoptera: Rhinotermitidae). It cause 68-96% mortality in termites at 5 ppm (vol: vol) (Raina A et al., 2007). Similarly, *Jatropha curcas* L. (Malpighiales: Euphorbiaceae), nut oil shows repellent activity against the Philippine milk termite *Coptotermes vastator* Light (Isoptera: Rhinotermitidae). *Jatropha curcas* oil induced reduction in tunneling activity and increase mortality in *C. vastator*. Behavior of termites exposed to sand treated with *J. curcas* oil indicated that it is toxic or repellent to *C. vastator* (Acda 2009).

D. Termite control by plant Latex

Plants produce large amounts of secondary metabolites in their shoots and roots for their defense. They store these secondary metabolites in those parts of the plant where the probabilities of invasion by insect are higher. These secondary metabolite benefits plant under herbivore attack (Huber et al., 2016). One of the secondary metabolite produce by plants for their defense is latex. Plants that belong to certain families are well known to exude a milky liquid if they are injured. This has been called latex due to its resemblance to milk. The latex is secreted by 10% of plant families to prevent plants from chewing hervivory (Ramos et al, 2019). The secretion of latex by plant is under the control of genetic, environmental determinants and hormones (Agrawal et al, 2019).The plants families that produce copious amount of latex are Euphorbiaceae, Asclepiadaceae, Moraceae, Caricaceae, Papaveraceae, Apocynaceae, Cannabaceae and Asteraceae (Sytwala et al., 2015, Lewinsohn et al., 1991). Some common latex secreting plants from family Euphorbiaceae are Hevea *brasiliensi*, *Euphorbia bicolor*, *Synadenium grantii*, *Sapium glandulosum*, *Jatropha gossypiifolia*, *Hura epitans* and *oton urucurana*. Major latex secreting plants from Moraceae are *Ficus carica*, *Maclura tinctoria*, *Maclura pomifera*, *Brosimum gaudichaudii*, *Antiaris toxicaria*, *Artocarpus heterophyllus*, and *Dorstenia luamensis*. *Taraxacum koksaghyz, Scorzonera latifolia, Lactuca serriola, Parthenium argentatum, Solidago virgaurea, Artemisia annua* are common latex bearing plants from family Asteraceae. *Cannabis sativa* and *Humulus lupulus* are two common latex secreting plants from family Cannabaceae (Metcalfe et al., 1967). **(Table.1)**

The family Apocynaceae is one of the largest and important families in angiosperm. Many members of this family secret milky latex if they are injured (Chan et al 2016). The member of family Apocynaceae is widely distributed and many of which are used in folk medicine as well as in agriculture. Over the past, they have received considerable phytochemical and biological attention due to their various biological activities (Wu et al, 2009).The common latex secreting plants of family Apocynaceae are *Allamanda cathartica, Alstonia angustiloba,Calotropis procera, Catharanthus roseus, Cerbera floribunda*, *Dyera costulata, Nerium oleander, Plumeria alba, Vallaris glabra, Hancornia speciosa, Acokanthera oblongifolia, Apocynum cannabinum, Thevetia peruviana*, *Rauvolfia serpentine, Plumeria rubra, Tabernaemontana divaricata* and *Himatanthus drasticus* (Bhadane et al, 2018) **(Table.2).**

The tissues that are responsible for secretion of the latex are called laticiferous tissues. This tissue consists of thick walled, greatly elongated and much branched ducts containing milky or yellowish colored liquids (Ramos et al., 2019). More than 12.000 vascular plants possess laticiferous tissues frequently distributed throughout the body of the plant (Hagel et al., 2008). They contain numerous nuclei which lie embedded in the thin lining layer of protoplasm. They irregularly distributed in the mass of parenchymatous cells. Latex cell is also called as "non-articulate latex ducts", these ducts are independent units which extend as branched structures for long distances in the plant body (Dussourd et al., 2019). They originate as minute structures, elongate quickly and by repeated branching ramify in all directions but do not fuse together. Thus, they don’t form a network as in latex vessels found in many latex secreting plant families such as Papaveraceae, Compositae, Euphorbiaceae and Moracesae (Rosa et al., 2019).

Plant latex is exuded from latex secreting plants; due to color resemblance to milk these are also given names milkweed. Plants in the Apocynaceae "Dogbane" family & the "Milkweed" family (Asclepiadaceae) are renowned for their latex production. Plant latex is exuded from the points of plant damage caused either mechanically or by insect herbivory (Tasca JA et al., 2018). The ten genera of family apocynaceae which produce copius amount of latex are *Allamanda*, *Alstonia*, *Calotropis*, *Catharanthus*, *Cerbera*, *Dyera*, *Kopsia*, *Nerium*, *Plumeria* and *Vallaris* (Chan EW et al., 2016).

Numerous components from extracts and latex of apocynaceae are identified and plants of this family have with a polyvalent therapeutic activity (Cristina et al, 2014). Plant latex are potential source of bioactive compounds against post harvest pathogens, including insects and microbes (Sibi et al., 2013). The latex secreted from the members of family Apocynaceae are rich in cardenolides, proteiase, alkaloids, terpenoids, steroids, flavonoids, glycosides, simple phenols, lactones, and hydrocarbons and other bioactive compounds (Bhadane et al., 2018). Cysteine proteases and chitin-related proteins and other proteins play major role in defending plants from herbivores (Kotaro konno et al., 2011). These ingredients are responsible for their antibacterial, antifungal, anthelmintic, cytotoxic, and insect-repellent activities (Salomé Abarca LF et al., 2019). They show synergism to prevent the plants from herbivory or infection (Ramos et al., 2019).

a) Bio-orgamic products from latxes

i. Cardenolides

Cardenolides are chief constituent of latex of family apocynaceae members. Cardenolides in latex are sporadically distributed across 12 botanical families, but dominate the Apocynaceae where they are found in > 30 genera (Agrawal et al, 2012). The leaves, flesh, seeds and juices of numerous plants from the genera of *Nerium*, *Thevetia*, *Cerbera*, *Apocynum* and *Strophanthus* in Apocynaceae family, are the major sources of natural cardenolides. So far, 109 cardenolides have been isolated and identified from this family (Wen et al, 2016). Although milkweed plants (Asclepias spp.) produce up to 200 structurally different cardenolides, all compounds seemingly share the same well-characterized mode of action, inhibition of the ubiquitous Na+/K+ ATPase in animal cells (Züst et al, 2019). Milkweeds in the genus Asclepias are a classic chemically defended clade of plants with toxic cardenolides (cardiac glycosides) and pressurized latex employed as anti-herbivore weapons (Rasmann et al, 2009).

Cardenolides are highly specific inhibitors of an essential ion carrier, the sodium pump. In insects exposed to both kinds of toxins, carriers either enabling the safe storage of the compounds away from the activating enzymes or excluding the toxins from sensitive tissues, play an important role as anti-feedent in termites (Dobler et al., 2011). Cardenolides are also known as cardiac glycosides (CGs) and members of this class are of clinical use and these are used to make medicine as arrow poisons, abortifacients, heart tonics, emetics, and diuretics as well as in other applications. The major use of CGs today is based on their ability to inhibit the membrane-bound Na+/K+-ATPase enzyme, and they are regarded as an effective treatment for congestive heart failure (CHF), cardiac arrhythmia and atrial fibrillation (El-Seedi et al., 2019).

Four cardenolides were isolated from *acokanthera oblongifolia* i.e. acovenosigenin a 3-*o*-*α*-l-acofriopyranoside, 14-anhydroacovenosigenin a 3-*o*-[*β*-d-glucopyranosyl-(1″→4')-*o*-*α*-l-acofriopyranoside], 14-anhydroacovenosigenin a 3-*o*-[*β*-d-glucopyranosyl-(1″→4')-*o*-*α*-l-acovenopyranoside], 14-anhydrodigitoxigenin 3-*o*-*β*-d-glucopyranoside and acospectoside a show significant anti-feedent activies against termites (Pecio et al., 2019). Similarly, ischarin and ischaridin from *calotropis procera* show termicidal activity (Sweidan et al., 2015). Cerberin a cardenolide named isolated from *Cerbera odollam* proven to be toxic to termites and cause significant mortality (Menezes et al., 2018). Three new cardenolides from *Nerium indicum* reported namely 3-beta-O-(beta-D-diginosyl)-14,15alpha-dihydroxy-5alpha- card-20(22)-enolide, uzarigenin and cardenolide N-1and all of these have termicidal activitities (Wang et al., 2009). A cardenolide named 15beta-hydroxycardenolides isolated from *Calotropis gigantean* also show toxicity against termites (Seeka et al., 2010). Cardenolide 6'-hydroxy-16alpha-acetoxycalactin isolated from *Pergularia tomentosa* act as termicides through the inhibitor of Na+/K+-ATPase (Piacente et al., 2009). *Asclepias curassavica* latex contains cardenolides named 12beta, 14beta-dihydroxy-3beta, 19-epoxy-3alpha- methoxy-5alpha-card-20(22)-enolide 12beta-hydroxycalotropin, it is highly toxic to termites (Li et al., 2009) **(Table 3).**

ii. Alkaloids

Indole alkaloids are also major components of the latex in latex secreting plants. It attracted the attention because of their therapeutic properties, being anti-inflammatory, antinociceptive, antitumoural, antioxidant, insecticidal and antimicrobial. These compounds present a wide structural diversity, which is directly related to the genera of the producing plants, as well as the biological activities (Rosales et al., 2012). Their biosynthesis has involved the formation of reactive intermediates by responsible enzymes to elaborate several different chemical scaffolds. Modification of scaffolds through different substitution reactions has produced chemically diverse MIAs and related biological activities (Williams et al., 2019).

The alkaloids vinblastine and vincristine are bisindole alkaloids derived from coupling vindoline and catharanthine, monoterpenoid indole alkaloids produced exclusively by the Madagascar periwinkle (*Catharanthus roseus*). These are used for insect suppression of insect population (Liscombe et al., 2011). Aspidospermidine, vincadifformine, 1, 2-

dehydroaspidospermidine, goniomitine, and quebrachamine, five Aspidosperma alkaloids distributed within three structurally diverse topologies are synthesized from a single molecular scaffold, namely indole-valerolactam 6 (Mijangos et al., 2018).

The latex of *Ervatamia hainanensis* is a rich source of alkaloids. In this plant, nine new monoterpenoid indole alkaloids, ervatamines A-I (1-9), and five known ones (10-14) are isolated. Ervatamine A (1) is a ring-C-contracted ibogan-type monoterpenoid indole alkaloid with an unusual 6/5/6/6/6 pentacyclic rearranged ring system. Ervatamines B-E (2-5) display a nitrogen-containing 9/6 ring system, which is rarely observed in nature. The ephemeris ervatamines B (2) and C (3) possess a 22-nor-monoterpenoid indole alkaloid carbon skeleton, which was only found in deformylstemmadenine (Zhang et al., 2015). Iridoids alkaloids are markers of oviposition and feeding preference to species which have became specialist feeders. Some herbivore species evolved to the point of been able to sequester iridoids and use them as defenses against their predators. However, iridoids also exhibit anti-insect properties, and therefore they may be good lead molecules to develop botanical pesticides (Castillo et al., 2010).

The alkaloids found in the latex possess insecticidal properties and also act as molluscides, acaricides, nematocides, fungicides and bactericides. Pure alkaloids as well as water and/or alcohol extracts cause lethal and sublethal effects in insects, which is important from the economical point of view (Chowański et al., 2016). Iridoid alkaloids possess good to excellent activities against phytopathogenic fungi *Fusarium graminearum* (LC50 value of 34.5 μg/mL with a 95% confidence interval of 33.4-35.5 μg/mL), *Rhizoctonia solani* (18 μg/mL, 15.7-20.8 μg/mL), and *Botrytis cinerea* (26 μg/mL, 22.4-30.4 μg/mL), thereby emerging as a potential new fungicidal lead. Moreover, iridoid alkaloids also exhibited good insecticidal activity against insects and could be used as commercial insecticide rotenone (35.4 μg/mL, 95% confidence interval 22.2-56.4 μg/mL) (Xia et al., 2020).

The alkaloid rauvomitorine A-I and C-9-methoxymethylene-sarpagine are major constituents of the latex of *Rauvolfia vomitoria*, it show toxicity against termites through acetylcholinesterase inhibitory (AChE) activities (Zhan et al., 2020). The alkaloids namely melotenine A and aspidosperma isolated from the latex of *Melodinus axillaris*, it proven to be toxic against termites (Fang et al., 2019). Similarly, *Tabernaemontana bufalina* latex contains alkaloid taberhaines which show toxicity against termites through inhibition of xanthine oxidase (Shi et al., 2019). The alkaloids melodinhenines A-F and melodinines isolated from the latex of *Melodinus henryi have* anti-termite properties (Ma et al., 2014 and He J et al., 2019). Alkaloids from *Tabernaemontana divaricata* named Taberniacins A and B show anti-termite efficacy (Hirasawa et al., 2019). Alkaloids named melotenuines A-E obtained from *Melodinus tenuicaudatus* proven to be toxic against termites (Liu et al., 2019). Alkaloids leucophyllinines A and B isolated from *Leuconotis eugeniifolia* show antiplasmodial activities and toxic to termites (Tang et al., 2019). **(Table.4)**

iii. Peptidases

Latexes from the family apocynaceae are rich in cysteine-protease activity. Cysteine proteases, such as ficin and bromelain, show toxicity against termites. Thus, plant latex and the proteins in it, cysteine proteases in particular, provide plants with a general defense mechanism against herbivorous insects (Konno et al., 2004). Cysteine peptidases (EC 3.4.22) are the most abundant enzymes in latex fluids. Their activity mainly related to defense against phytopathogens. All peptidases exhibited optimum activity at 35 °C and followed Michaelis-Menten kinetics. The peptidases promoted membrane permeabilization, morphological changes with leakage of cellular content, and induction of ROS in *F. oxysporum* spores (Freitas et al., 2020). The latex of *Calotropis procera* is a rich source of proteolytic activity. This latex is known to contain two distinct cysteine peptidases: procerain and procerain B. These enzymes exhibited discrete differences in terms of enzymatic activity in a broad range of pH and temperature conditions and contained identical N-terminal amino acid sequences (Ramos et al., 2013). The presence of enzymatic activities in latex from *C. procera* may confirm their involvement in the resistance to phytopathogens and insects, mainly in its leaves where the latex circulates abundantly (Freitas et al., 2007).

The latex from *Thevetia peruviana* is rich in plant defense proteins, including a 120 kDa cysteine peptidase with structural characteristics similar to germin-like proteins. Latex of Thevetia peruviana (Pers.) contains 33 proteins (86 %) including storage proteins. It also contains peptidase inhibitor, cysteine peptidases, peroxidases and osmotins (de Freitas CD et al., 2016). Asclepain is a plant cysteine protease. It is a successful enzyme for biocatalysis of protein hydrolysis processes at alkaline pH (Torres et al., 2019). The enzyme, named philibertain g I, is the most basic component present in latex of *Philibertia gilliesii* Hook. et Arn., Apocynaceae. The new protease was inhibited by E-64 a cysteine peptidases inhibitor Philibertain g I show the higher degree of identity (73%) with caricain, one of the *Carica papaya* endopepetidases (Sequeiros et al., 2005). Cysteine proteases from some members of family apocynaceae plants latex exhibited both thrombin and plasmin like activities. Plant latex used to stop bleeding and wound healing by traditional healers all over the world (Shivaprasad et al., 2009). Latex-bearing plants also host insects. The peptidase inhibitors of laticifer origin inhibited the proteolysis of gut homogenates. Although latex peptidase inhibitors inhibit gut peptidases (in vitro), the ability of gut peptidases to digest latex proteins (in vivo) regardless of their origin seems to be important in governing the resistance-susceptibility of termites (Ramos et al., 2015).

Few cysteine CpCP1, CpCP2, and CpCP3 have been isolated isolated from *Calotropis procera*, these compounds show anti-fungal properties through promoting membrane permeabilization, morphological changes with leakage of cellular content, and induction of ROS (Freitas et al., 2020). From *Araujia angustifolia* latex cystein peptidases named Araujiain is isolated; it shows proteolytic activity and can be used as a potent termicidal agent to kill the symbionts of termites (Obregón et al, 2011). Cg24-I a cysteine is a peptidase isolated from *yptostegia grandiflora* proven to be toxic to phytopathogens (Ramos et al., 2014). Cysteine peptidases named 12, 16-dihydroxicalotropin, calotropin, corotoxigenin 3-O-glucopyranoside and desglucouzarin isolated from the latex of *Asclepias subulata*, it promote cell death through caspase-dependent apoptosis in termites (Rascón-Valenzuela et al., 2016). *Philibertia gilliesii* latex contains a cystein peptidase i.e. philibertain, it shows high proteolytic activity and can be used as termicides (Sequeiros C et al., 2016). Similarly, cystein peptidases from *Thevetia peruviana* named peruvianin-I exhibit high specific activity towards azocasein (de Freitas et al., 2016), Calotropin from *Asclepias curasavica* exert strong inhibitory and pro-apoptotic activity (Mo et al, 2016), procerain B from *Dregea sinensis* degrade α-casein (CN) (Zhang et al., 2015) and cystein peptidases ervatamin-A, ervatamin-B and ervatamin-C from *Ervatamia coronaria* show Anti-termitic activity (Ghosh et al, 2008). **(Table.5)**

iv. Flavonoids

Flavonoids are an important class of natural products; particularly, they belong to a class of plant secondary metabolites having a polyphenolic structure, widely found in fruits, vegetables and certain beverages. They have miscellaneous favourable biochemical and antioxidant efficacy (Panche et al., 2016). Methylated flavonoids showed anticancer, immunomodulation, insecticidal and antioxidant activities. Though methylated flavonoids are widely present in plants, their levels are usually low (Wen et al., 2017). In the latex of apocynaceae members, the chief flavonoids are genistein, biochanin A, apigenin, quercetin, and glyceollin. Among these Biochanin A is most effective in reducing fecundity and it also act as anti-feedent against *Coptotermes formosanus* Shiraki (Boué and Raina 2003). Flavonoids exhibit antioxidant activity and have a strong 1, 1-diphenyl-2-picrylhydrazyl (DPPH) and hydroxyl radical-scavenging ability with IC_{50} of 0.984 and 1.084 mg/g, respectively (Zhou et al., 2018).

The chief flavonoids from the latex of *Apocynum venetum* are plumbocatechin A, 8-O-methylretusin and kaempferol 3-O-(6″-O-acetyl)-β-D-galactopyranoside. All these compounds have antimicrobial activity and thus, can be used in termites control; they kill the symbionts of termites which lead to the death of termites (Kong et al., 2014). Similarly, flavonoids Kaemperol-3-O-rutinoside, quercetin-3-O-glucoside and kaemperol-3-O-glucoside isolated from *Holarrhena floribunda* show antioxidant activity (Badmus et al., 2016). Flavonoids named kaempferol 3-rhamnogluco-7-glucoside, kaempferol 3-rhamnogluco-7-galactoside, quercetin 3-rutino-7-glucoside and quercetin 3-rhamnogluco-7-glucoside from the latex *Vinca minor* show termicidal activity (Szostak et al., 1975). *Cynanchum acutum* latex contains flavonoids named kaempferol-3-O-β-xylopyranosyl-(1-2)-β-rhamnopyranoside, quercetin-3-O-β-xyloside, kaempferol-3-O-β-glucosid, quercetin-3-O-β-glucoside, kaempferol-3-O-β-rhamnopyranoside and kaempferol-3-O-β-d-neohesperidoside. Theses flavonoids have antiproliferative effects (Yildiz et al., 2017). Flavonoids naringenin, aromadendrin (dihydrokaempferol) and kaempferol are chief constituents of *Echites hirsute* latex, they show termicidal properties (Chien et al., 1979) and flavonoids isolated from *Trachelospemum jasminoides* named apigenin, apigenin 7-O-beta-glucoside, apigenin 7-O-beta-neospheroside, narngin and 6,8-di-C-glucopyanosylapigenin show anti-feedent activity (Tan et al., 2010) **(Table.6).**

v. Terpenes

Like alkaloids, the abundance of terpenes and their derivatives has been reported in many members of the family Apocynaceae. Terpinoids isolated from *Nerium oleander* are mainly oleandric acid, ursolic acid, betulinic acid, betulin, and derivatives of epoxydammarane 3β, 25-diol show significant anti-termitic activity (Fu et al., 2005). Among the various isolated terpenes, vulgarone B, apiol and cnicin exhibit significantly higher mortalities in termites. These are highly toxic compounds to termites (Meepagala et al., 2006). The terpenoids constitute the largest class of natural products and many interesting products are extensively applied in insect pest management such as termicides (Singh et al, 2015). In the latex of *Taraxacum koksaghyz* there are more than 13 triterpenes identified till now including pentacyclic compounds lup-19(21)-en-3-ol and its ketone lup-19(21)-en-3-one (Pütter et al., 2019). In the latex of *Euphorbia kansui*, there are 6 triterpenoids, one of them are identifies as euphane-3β, 20-dihydroxy-24-ene. The ring part of tetracyclic triterpenoid compounds can insert into the hydrophobic core of h11β-HSD1 and the alkane chain orientates toward the outside. This is the reason why it is used in diabeties (Guo et al., 2012).

Major terpenes in the latex of *Periploca somaliensis are* perisomalien A, lupeol acetate, *β*-amyrin cycloart-23*Z*-ene-3β, 25-diol and *β*-sitosterol-3-*O*-*β*-D-glucopyranoside. These compounds show toxic effects against termites (Jabal et al, 2020). Similarly, terpenes from *Epigunum griffithianum* named saponin and epigynosides A-B show immunosuppressive activities (Wang et al, 2020). Terpenes named saponins from *Gymnema sylvestre* show anti-microbial activities (Fabio et al, 2014). Terpenes ursolic acid isolated from *Pleiocarpa pycnantha* show toxic against termites (Omoyeni et al, 2014). *Pentalinon andrieuxii* latex contains urechitol A terpenes show anti-feedent activity (Hiebert-Giesbrecht et al, 2016). (**Table.7**)

vi. Sterols

Sterols, also referred as phytosterols or steroid alcohols, are present with potential bioactivity in several Apocynaceae plants. Bioactivities shown by sterols include hepatoprotective, anti-inflammatory, andantihyperlipidemic activities (Bhadane et al., 2018). Among all members, *Wrightia tinctoria* and *Alstonia scholaris* are quite rich with different kinds of phytosterols. Stigmasterol, β-sitosterol, and campesterol are commonly present in different parts of these plants (Adotey et al., 2012). The predominant sterols in plants of family apocynaceae are β-sitosterol, campesterol, and stigmasterol (Valitova et al., 2016). These show play important role in insect growth and development and its scarcity seize them at any stage of life including larval to adults forms. Sterols show strong insecticidal activities against adult termites and a negative impact on fecundity (Beaulieu et al., 2018).

Sterols pentalinonside and pentalinonsterol isolated from *Pentalinon andrieuxii* show termicidal activity (Pan et al., 2012). *Alstonia scholaris* latex contains sterols named poriferasterol, epicampesterol, β-sitosterol, 6β-hydroxy-4-stigmasten-3-one, and ergosta-7,22-diene-3β,5α,6β-triol show anti-termitic activities (Wang et al., 2017). Latex of *Gymnema sylvestre* contains sterols named beta-sitosterol, campesterol and stigmasterol. All these copmpounds show anti-feedent activity against termites (Vats et al., 2013). Similarly, *Cynanchum limprichtii* latex contains limproside A and limproside B which are proven to be toxic against termites (Liu et al., 2018). β-sitosterol and β-daucosterol are chief sterols found in the latex of *Periploca forrestii*, they are highly toxic to termites (Zhang et al., 2016). In the latex of *Pergularia tomentosa* 3-acetyltaraxasterol, 3-taraxasterol and 16α-hydroxytaraxasterol-3-acetate are chief sterols which are responsible for the significant mortality in termites (Babaamer et al., 2012) **(Table.8).**

vii. Simple phenolic compounds

Simple phenolic compounds are mostly derivatives of hydroxybenzoic and hydroxycinnamic acid, which contain C6C1 and C6C3 skeleton with carboxyl group attached to aromatic ring (Dewick 2002). They have been studied for potential bioactivities in some members of family Apocynaceae (Bhadane et al., 2018). There are total 16 simple phenolic compounds reported from the different species of *Carissa* genus (Kaunda and Zhang. 2017). Among them, 5 simple phenolic compounds named syringic acid, vanillic acid, p-coumaric acid, caffeic acid, and chlorogenic acid are reported from *Carissa carandas* fruits alone (Patil et al., 2012). Later, scopoletin and chlorogenic acid are also reported from *Carissa carandas* with anti-inflammatory activity (Begum et al., 1999). Chlorogenic acid, vanillic acid, along with gallic acid, hydroxytyrosol, and ferulic acid, are later reported from *Catharanthus roseus* leaves (Choi et al., 2004).

The phenolic compounds show insecticidal activity and use in insect control because of their odor, color and taste (Nieto et al., 2018). These compounds also exhibit many physiological functions, such as insecticidal, molluscicidal and antimicrobial activities, as well as various kinds of biological activities such as antioxidant, cytotoxic, anti-diabetic and anti-inflammatory properties (Lin et al., 2019). Phenolic compounds named integracin D, (7'R, 8'S, 8S) -8-hydroxyisoguaiacin, (2R, 3R) pinobanksin-3-caffeoylate and threo-8S-7-methoxysyringylglycerol found in the plants as natural compounds show significant anti-oxidative activity and protein kinase inhibitory activity. The ellagic acid derivatives have insecticidal activity against a number of insects including termites (Shi et al., 2010).

Phenolic compound named protocatechuic acid, catechin and quercetin isolated from *Hancornia speciosa* act as a deterrent for termites (Bastos et al., 2017). Similarly, the phenolic compounds present in the latex of *Asclepias linaria* named p-coumaric and ferulic acid show toxic effect against termites (Sánchez-Gutiérrez et al., 2019). Phenolic acids present in the latex of *Carissa macrocarpa* have antimicrobial activities (Souilem et al, 2019). The phenolic compound present in the latex of *Cynanchum wilfordii* is 2-*O*-β-laminaribiosyl-4-hydroxyacetophenone responsible for significant mortality in termites (Uchikura et al., 2018). **(Table.9)**

viii. Lignans

There are only few lignans reported from the members of family apocynaceae. A lignan named reveledcarinol as phenolic lignan isolated from the extract of genus *Carissa carandas* (Pal et al., 1975). Later on, three new lignans namely (6R, 7S, 8S)-7a-[(b-glucopyranosyl) oxy]lyoniresinol, carissanol, and (-)-nortrachelogenin isolated from the stem of Carissa carandas (Bhadane et al,, 2018). Recently, syringaresinol 4-O-b-glucopyranoside was isolated from *Vinca major* (Sohretoglu et al., 2013). A new lignan glycoside, (+)-pinoresinol 4-O-[6″-O-vanilloyl]-β-d-glucopyranoside isolated from the latex of *Calotropis gigantea* show insecticidal activity (Parhira et al., 2014). **(Table.10)**

b) Insecticidal activity of latex

Latex components if used as insecticide are are safe and do not put any adverse effects on environmental quality and non target organisms including human health (Ghosh et al., 2012). Latex ingredients are bioactive substances and are useful as medicines and pesticides (Konno et al., 2006). Plant latex provides an alternative way in the insect control strategy. These are secondary chemicals synthesized by plants (Tan et al., 2018) which are non-toxic and biodegradable and can be used to control insects as an alternative to chemical insecticide (Govindarajan et al., 2013). The latex from the different plant families used since long time in medicine as well as in the control of some insects (Hoekou et al., 2016). Latex from various plants shows diverse biological activities against bacteria, fungi, viruses, protozoans, nematodes and insects. It also shows some anti-cancer properties and used since long times as disinfectant, anticoagulant, anti-inflammatory, antioxidant and antiproliferative agent (Upadhyay 2012). Latex fractioned with different solvents shows a variable degree of anti-termitic activities. In the latex of *Euphorbia kansui*, there are 6 triterpenoids, one of them are identifies as euphane-3β, 20-dihydroxy-24-ene. All these compounds have insecticidal activity (Guo et al., 2012). The insecticidal activities of latex are dose-dependent (Chandrasekaran et al, 2018). In the latex of Euphorbia Tirucalli L total phenolic content ranged from 7.73 to 30.54 mg/100 g gallic acid equivalent and it show higher antioxidant activities. The extracts of Euphorbia tirucalli L. have excellent antioxidant capacity and moderate antimicrobial activity (de Araújo et al., 2014).

The constituents of latex are well known in some plant families for their phytotoxic, insecticidal, cytotoxic, antibacterial and antifungal activities (Ayatollahi et al., 2010). Latex fractioned with different solvents shows variable degree of anti-termitic activities. Among various soluble latex fractions from different plants, chloroform fractions show highest toxicity against insects. The insects show comparative tolerance in the course of increasing age and time (Nikkon et al., 2011). Secondary metabolites and their secretary structures are commonly help the plant in their defense. Most of them act as insect growth control agents (Huber et al., 2016). This is the main reason insects feed on plants, and died due to the plant secret copious amount of latex to defend themselves (Dussourd et al., 2019).

The latex from the leaves of *Aloe trigonantha* is well known for their antibacterial and antifungal properties. Insects when feed on hardwood trees, the elongate canals follow leaf veins and contain latex under pressure; rupture which causes the immediate release of sticky poisonous exudates (Dussourd et al., 2015). Plant possesses highly specialized metabolite diversity in hotspots, geographic regions, which exhibit strong reciprocal selection on the interacting species (Ernst et al., 2019). The latex of *Garcinia morella* (Gaertn.) possesses many bioactive compounds with insecticidal activities. The major compounds in the latex are 5-Oxohexanenitrile (18.7%), phenol, 2, 4-bis (1, 1-dimethylethyl) - (24.64%) and Hexadecanoic acid (22.85%). The latex shows toxicity against many insects (Murthy et al., 2017). In cucurbit plants, phloem latex exudates from phloem from cut sieve tubes used to make defense against herbivores (Gaupels et al., 2012). In the latex of *Taraxacum koksaghyz* there are more than 13 triterpenes identified till now including pentacyclic compounds lup-19(21)-en-3-ol and its ketone lup-19(21)-en-3-one (Pütter et al, 2019).

A major component of the latex aloesin a C-glycosylated chromone exhibits antibacterial activity against pathogens (Megeressa et al., 2015). In the latex of mulberry (*Morus* sp.) latex posses protein a and b (LA-a and LA-b). These proteins showed small but significant chitinase and chitosanase activities. LA proteins hydrolyze chitin surface of insects (Kitajima et al., 2010). *Lobelia siphilitica* shows reduced latex production and high herbibores attack (Parachnowitsch et al., 2012). The *Carica papaya* latex solvent extracts showed larvicidal properties against a number of insects (Chandrasekaran et al., 2018).

Plants also bear morphological structures i.e. waxes, trichomes, and latices make the feeding more difficult for the insects (Fürstenberg-Hägg et al., 2013). Plants release volatile compounds in air to repel herbivores, attract insect predators. Latex triterpenes are exclusively synthesized via the mevalonate (MVA) pathway are proven to be toxic to insects (Gastaldo et al., 2019). Jaburetox is a recombinant peptide derived from the latex of *Canavalia ensiformis* (Jack Bean) urease that presents biotechnological interest since it is toxic to insects of different orders. Its toxic effect leads to hemocyte aggregation and hemolymph darkening, among other effects. Nanomolar doses of Jaburetox triggered cation-dependent, aggregation of hemocytes in insect larvae and adults (Fruttero et al., 2016).

From the seeds of *Albizia procera* (ApCP) a 25 kDa cysteine protease extracted, it show insecticidal activity and since long times it used as nanocarriers against stored grain insect pests. Its insecticidal activity of ApCP much improved when it encapsulated with graphene quantum dots (GQDs) (Batool et al., 2020). The sites of protease toxic activity range from the insect midgut to the hemocoel (body cavity) to the cuticle. So these proteases can be used as potential pesticides in place of synthetic insecticides (Harrison et al., 2010). The leaf latex of the *Aloe* species is traditionally used for the treatment of various pathogenic conditions and in insect control. The leaf latex ingredients are found to be active against microbes and insects (Asmerom et al., 2020).

Milkweeds in the genus *Asclepias* are a classic chemically defended clade of plants with toxic cardenolides (cardiac glycosides) and pressurized latex employed as anti-herbivore weapons (Rasmann et al., 2009). Plant latices with various formulations are toxic by contact or airborne compounds against termites. However, high termite mortality is occur by forced direct or forced indirect exposure to the plant material. So, extracts of plants could be used for soil treatments to protect a food substrate against *R. santonenis* infestation (Bläske et al., 2001). Subterranean termites are major pest worldwide, causing billion of loss in crops and household things annually. The latex provides an alternative way to control termites. Use of lattices in control of termites is eco-friendly and environmentally safe. The various latex components from family apocynaceae directly affect termites acting as anti-feedent, repellent and toxic.

The latex of *Euphorbia kansui* contains five ingenane compounds, 1-5, including kansuinins A and B. The ingenane compounds have termiticidal activity against the Japanese termite, *Reticulitermes speratus*. The ingenane compounds 1 to 5 caused 100% mortality in *R.*

speratus at 50, 25 and 12.5 microg/disk. The compounds 1 to 5 show more termiticidal activity than kansuinins A and B and their derivatives (Shi et al., 2008). In the latex of Chinese cedar (*Cryptomeria fortunei* Hooibrenk), α-terminal is the chief constituents which show antitermitic activity of against *Reticulitermes chinensis*. The LC50 values of α-terpineol are found to be 2.80 mg/mL (Xie et al., 2013).

Three pterocarpans, (-)-homopterocarpin (1), (-)-pterocarpin (2), and (-)-hydroxyhomopterocarpin (3) and the sesquiterpene alcohol, (+)-pterocarpol (5) obtained from dichloromethane extract of the heartwood of *P. macrocarpus*, among these natural products, the most active insect antifeedant against *R. speratus* was 1. In comparision to sesquiterpene, pterocarpans show high antifeedant activity against subterranean termite, *Reticulitermes speratus* (Morimoto et al., 2006). When chloroform extract of dry *Lantana camara* 'Mozelle' leaves, applied to the soil, the termite mortality is greatly increased. It causes 90% and 78% reduction in feeding, and approximately 52% mortality and 40% reduction in feeding at 0.212 and 0.106 mg/cm^2 concentration respectively (Yuan et al., 2012).

E. Termite control by synthetic pesticides

Synthetic compounds are widely used to control termite since long times. It can be applied in large areas and crop field. Synthetic chemicals are highly toxic to termites, but other non targeted organisms are also affected and its use also concern with environmental problems. The various synthetic pesticides used in termite control are fipronil, chlorpyrifos, bifenthrin, chlorantraniliprole, pyrethroid and many more. The control of subterranean termites is predominantly through the application of chemical barriers in the soil beneath and surrounding buildings. The chemicals used to repel or kill termites are the organophosphorus insecticide, chlorpyrifos, and the synthetic pyrethroid, bifenthrin. These are applied through surface sprays and subfloor injection by licensed pest control operators (Smith et al., 2002).

Fipronil is a broad-spectrum insecticide belonging to the phenylpyrazole chemical family. This is highly toxic to ustaceans, insects and zooplankton as well as to termites, rabbits and certain groups of gallinaceous birds (Charalampous et al., 2019). Fipronil is the most frequently used product to protect seedlings in the field for up to 6 months after application. (dos Santos et al., 2016). Soil treatments of fipronil and cypermethrin prevent eastern subterranean termite, *Reticulitermes flavipes* access in 75% of the homes. The number of active monitoring stations only declined within 2 m of the fipronil-treated zone. Hexaflumuron exhibited a reduction in activity for at least a 15-m radius (Ripa et al., 2007).

It is a potent disrupter of the insect central nervous system via interference with the gamma-aminobutyric acid (GABA-) regulated chloride channel. Fipronil degrades slowly on vegetation and relatively slowly in soil and in water (Tingle et al., 2003).

Chlorpyrifos, an organophosphorus insecticide, have been used as a termite control (Asakawa et al., 1989). It displays broad-spectrum insecticidal activity against a number of important arthropod pests. Chlorpyrifos is used in crops including rice, and soil application to control termites. Its various formulations of chlorpyrifos have been developed to maximize stability and contact with pests and minimize human exposure (Racke 1993).

Another synthetic compound used to control termites is bifenthrin. The embedded and immobilised bifenthrin is very well protected from free release and has a long-term stability allowing slow release with a high efficiency against termites at a low dose of 1.25 µg cm(-2) (Guan et al., 2011). Bifenthrin is more persistent than fipronil under all treatment conditions (Manzoor F et al., 2017). Altriset (Chlorantraniliprole) is another insecticide used to control termites. Its effectiveness depends upon the concentrations, distance, and application methods. 100% termite control is achieved at 100 and 50 µg/g and it shows greater efficacy applied prior to termite tunnel establishment in soil treatments (Barwary et al., 2015). Chlorantraniliprole exhibited a more delayed mortality on termites than fipronil in sand. In soil, chlorantraniliprole did not cause higher mortality to either donor or recipient termite. A greater number of donors died in the soil treated with fipronil at 14 h postinteraction, and higher death of recipients occurred at 60-ppm concentration tested. Thus, chlorantraniliprole show high mortality in substrate with low organic matter against termites (Gautam et al., 2011).

Termite workers exposed to sand and soils treated with chlorantraniliprole at 50 ppm exhibited delayed mortality and, for most of the exposure times, it took some time to observe 90-100% mortality in termite workers. Exposure to chlorantraniliprole-treated sand (50 ppm) for as little as 1 min stopped feeding and killed 90-100% of the workers (Saran et al., 2014). Chlorantraniliprole was highly toxic to termite workers in brief and continuous exposure across a range of concentrations from 5 to 100 ppm. It cause 100% mortality in the termites in 14 d. exposure route has no significant effect on chlorantraniliprole toxicity and chlorantraniliprole is highly active by feeding and contact (Buczkowski et al., 2012).

Several rare and common monosaccharides are toxic to Formosan subterranean termite, *Coptotermes formosanus* Shiraki. Myo-Inositol and phytic acid, which are nontoxic to mammals, can be used as potential termite control compounds. Myo-Inositol show toxicity at 160.2 to 1,281.7 μg/mm concentration and its toxicity is concentrtion-dependent (Veillon et al., 2014). A cellulose-acetate powder containing either 0.05% wt: wt or 0.25% wt: wt chlorfluazuron (Requiem, Ensystex, Fayetteville, NC) are caable of eliminating colonies of the xylophagous mound-building subterranean termite *Coptotermes acinaciformis* (Froggatt). Colony decline can be seen 12 wk after bait application (Peters et al., 2003). Silafluofen is used as an agricultural insecticide for 15 years since 1995 for various plants, especially useful for paddy rice protection because of its low fish toxicity. Silafluofen-based termiticides including emulsifiable concentrate (EC) and oil formulations are widely used for soil treatment and timber treatments (Katsuda et al., 2011).

There is little dissipation of chlorfenapyr in soil treated at the labeled rate for perimeter treatments for the prevention and control of termite infestations. Chlorfenapyr may be detected in soil immediately below the initially treated soil in the packed soil columns. This is likely due to settling of soil. The soil treated with display chlorfenapyr slow-acting properties regarding toxicity to termites (Peterson and Davis 2013).

2, 4-D amine salt (2,4-D), Vestamine and Ultrazine used to control termites since long times. It is highly toxic to termites and chiefly used in the control of *Macrotermes bellicosus* (Ejomah et al., 2020). Fipronil is another synthetic compounds used to control termites Macrotermes bellicosus. It is highly toxic to termites and cause significant mortality in termites at 0-64 ppm and its act as a neurotoxic. Similarly, Imidacloprid also cause significant mortality at 0-250 ppm and it is also a neurotoxic (Iqbal et al., 2018). Chlorantraniliprole is used in the control of termite species *Reticulitermes flavipes.* It is act as anti-feedent at 5-ppm concentration (Buczkowski et al, 2012). Similarly 1, 4-dichlorobenzene is also used in the control measure against *Reticulitermes flavipes.* It is used to protect woody thing from termites (Morita et al., 1977).

Similarly, Mancozeb is widely used in the control of termites. It’s proven to be an anti-feedent at 100 g/L (Brandford et al., 2019). Other synthetic compounds used in the control of termites are Chlorpyrifos, Chlordane and Spinosad. These compounds are used against *Coptotermes formosanus* (Phillips et al, 2010). Chlorpyrifos is chiefly used in agriculture as well as soil barriers. It is highly effective at 10 mg/kg soil (Das et al, 2015). Spinosad is effective against *Coptotermes formosanus* at 50 ppm (Bhatta et al, 2016). (**Table.11**)

F. Biological control of termite

Natural enemies of insects are employed for planned invasions, with the opportunity to select both the invader and the invaded environment (Abram and Moffat 2018). For biological control of insects, various groups of pathogens mainly bacteria, fungi and viruses are employed to kill insects. Biopesticide show multiple effects on life and life cycle of insects. Biopesticides cause modification of development of insect and behavior exerts unique approach for management of insect population. Pathogens are host specific and cause diseases in insects. Mainly three approaches are used for biological pest control: in first phase natural enemies of insects are introduced, a second phase large population of natural enemies is administered for quick pest control; in third or inoculative phase maintain natural enemies through regular reestablishmen. For better control and operational level various predators, parsitoids, pathogens and competitors are employed.

In biological control introduction of specialist natural enemy of insects are employed, these are species and show no negative effects on the environment (Grønvold et al., 1996). There are a wide variety of natural predators of termites are available which can control highly invasive species of termites (Mills and Heimpel 2018). There are hundreds of different species of birds that love to make a meal out of termites. These include redheaded woodpecker, chickens, doves, sparrows, spotted eagle owls, starlings, swifts, weavers and Egyptian goose. There are many species of insect which eat termites such as oogpister beetle, ants, assassin bugs, flies, spiders and wasps (Culliney et al., 2000). Spiders use their inherent abilities to catch termites in flight. With a well-placed web, arachnids will enjoy a full meal more often than not (Petráková et al., 2015). Perhaps one of the biggest predators of termites is the ant. There are six different species of ants that will actively seek out and prey on termites. Ants live similarly termites, utilizing widespread colonies to further their survival (Fayle et al., 2015). Predators of termites don’t just live above ground. eatures like moles and shrews will certainly help themselves to a meal should they stumble upon a termite colony. Some may be surprised to learn that primates can also be included on the list of natural predators of termites. Some reptiles are also fed on termites, reptiles geckos, lizards and snakes are good termite eater. Frogs and some mammals like Aardvarks, anteaters, armadillos, bats and primates is termite eater causing a significant decrease in termite population (Sahayaraj et al., 2018). **(Table.12)**

I. Microbial control

In recent years, increasing attention has been directed to biological methods of control termites. Many species of bacteria and fungi are parasitoids on termites and thus, they can be used termite control agents (Burges et al., 1982). In the biological control natural enemies of termites such predator, parasitoids: viruses, bacteria, fungi and nematodes used as components of integrated pest management (Lacey et al., 2015). The bacterium *Trabulsiella odontotermitis* is associated with fungus-growing termites (Sapountzis et al., 2015). This bacterium serves as a 'Trojan Horse' for expression of gene products in termite colonies. When engineered strains of *T. odontotermitis* transformed with a constitutively expressed GFP plasmid fed on termites, it expressed GFP in the gut and formed a biofilm in the termite hindgut and *T. odontotermitis* can serve as a 'Trojan Horse' for spreading gene products in termite colonies (Tikhe et al., 2016).

The entomopathogenic fungus *Metarhizium anisopliae* is widely used as biocontrol agents against many insect pests. *M. anisopliae* TK29 had desirable attributes for the development of a mycoinsecticide against *C. formosanus*. Conidial spore of potential isolate of *M. anisopliae* (TK29) cuases high mortality in termites (Keppanan et al., 2018). Alates of the Formosan subterranean termite, *Coptotermes formosanus* Shiraki infected with a fungus *Metarhizium anisopliae* show significant mortality. A single fungal isolates, C4-B caused rapid mortality of Formosan subterranean termite alates. When Formosan subterranean termite alates are exposed to a known concentration of C4-B spores of 10 (6) spores/microl, it show 100% of the alates and worker termites infected with 10(6) and 10(5) spores/microl also show 100% of the workers (Wright et al., 2005). Termites, *Odontotermes* spp. workers are susceptible to entomopathogenic fungal isolates through the direct spraying of conidia suspensions at 1 × 108 conidia/mL. all entomopathogenic fungal strains cause 100% mortality. The most virulent isolates are *Metarhizium brunneum* Cb15-III; the *M. anisopliae* isolates ICIPE 30 and ICIPE 60; *Hypocrea lixii* F3ST1; and the *Beauveria bassiana* isolates ICIPE 279, ICIPE 706 and ICIPE 662 (Ambele et al., 2020).

The fungus *Beauveria bassiana* is combined with the non-repellent chemical termiticide imidacloprid show synergistic effect. When fungal strain, *B. bassiana* ATCC 26037 combined with imidacloprid, it causes 82.5% mortality in comparison to mortality rate of

65.0% for the fungus alone. When another fungus *Isaria fumosorosea* (Ifr) combined with the bacterium *Bacillus thuringiensis* (Bt), it also increases the mortality rate in termites in concentration dependent manner (Wright et al., 2013). Trehalase is the hydrolytic enzyme that catalyzed the hydrolysis of trehalose to glucose. Trehalase activity in digestive tract and carcass of *Odontotermes feae* is higher than that in wood-feeding termite. Validamycin is used to inhibit trehalase activity of *O. feae* in vivo and caused high mortality, indicating that this trehalase inhibitor is valuable tools for termite control (Tatun et al., 2014).

The fungal species I*saria fumosorosea* cause significant mortality in *Coptotermes formosanus* by producing infectious conidia and another fungal species *Metarhizium anisopliae* also infect *Coptotermes formosanus* and cause alarm, aggregation and defensive reactions in termite species (Wright et al., 2012). Similarly, *Fusarium* infects *Reticulitermes flavipes* and produce Infectious conidia which cause significant mortality in termite (Teetor-Barsch et al., 1983).

Bacteria named *Trabulsiella odontotermitis* spread gene products in termite *Coptotermes formosanus* and thus, engineered *Trabulsiella odontotermitis* species proven to be an alternative way to control termites (Tikhe et al 2016). Similarly, another bacterial species, *Photorhabdus luminescens* is able to express termicidal genes in *Coptotermes formosanus* (Zhao et al, 2008). *Macrotermes gilvus* (Hagen) soldier termites are parasitoid by parasitic Diptera the scuttle fly, *Megaselia scalaris* (Loew) (Diptera: Phoridae). Thus *Megaselia scalaris* could be used as a biological control agent of termites (Noknoy et al, 2020).

Entomopathogenic nematodes (EPNs) which are also called beneficial nematodes commercially used to control insect pests. A wide range of EPNs is effective against various termite species. (Lacey et al, 2015). Various strains of nematodes *Heterorhabditis bacteriophora* such as *H. bacteriophora* Poinar (IRQ.1 strain) and *Steinernema carpocapsae* are pathogenic to termites *Microcerotermes diversus* causing high mortality in termites (Al-Zaidawi et al, 2020). Another strain of *Heterorhabditis bacteriophora* Poinar (HP88 strain) able to infect and kill termite species *Heterotermes aureus* (Snyder), *Gnathamitermes perplexus* (Banks), and *Reticulitermes flavipes* (Kollar) (Yu et al, 2006). Similarly, two other nematodes such as *Termirhabditis fastidiosus*, *Rhabpanus ossiculum* are pathogenic to protozoan symbionts in termites gut, they kill the protozoan symbionts which ultimately results in the death of termites *Reticulitermes flavipes* and *Coptotermes* spp. (Massey 1971). Another nematode named *Steinernema riobrave* strain 355 has the capacity to infect

Heterotermes aureus, *Reticulitermes flavipes*, and *Coptotermes formosanus* termite species and causing significant mortality in them (Yu et al, 2010). **(Table.13)**

G. Behavioral control of termite

The behavior of termites is in the control of various agents such as physical conditions and pheromones. The foraging patterns of termites are strongly related to physiological limits in overcoming desiccation stress (Hu et al., 2012).

Groups of *R. flavipes* when exposed to several concentrations of commercial formulations of fipronil and indoxacarb then it is found increasing insecticide concentration resulted in a reduction in the ability of *R. flavipes* to walk, tunnel and form tunnel branches. Exposure of *R. flavipes* to 1, 10 or 50 mg L (-1) of fipronil or 50, 100 or 200 mg L (-1) of indoxacarb significantly reduce termite walking and tunneling and the number of tunnel branches (Quarcoo et al., 2012). The ground-applied termiticides affect the above-ground foraging behavior of *Coptotermes formosanus*. When Termites treated with three termiticides, viz. fipronil, imidacloprid and chlorantraniliprole, the termites treated with fipronil had the lowest percentage of survival (3%-4%). Termite survival ranged from 31% to 40% in the case of imidacloprid treatments and 10 ppm chlorantraniliprole when mixed in poison baits (Henderson et al., 2016).

Aggressive behavior is related to colony defense in the territories and feeding grounds. The distance among colonies and resource availability affect the aggression level and responses to chemical cues of *Nasutitermes aff. coxipoensis* (Holmgren) (Termitidae: Nasutitermitinae). Individuals from colonies with less resource show a higher number of fighting with neighbors than those from non-neighbors colonies (Ferreira et al., 2018).

*Reticulitermes virginicus (*Banks) would carry more sand into wooden blocks containing corpses compared to a corpse-free wooden blocks. During the decay of dead termites oleic acid, is released that is used by *R. virginicus* in corpse recognition. Oleic acid released significantly reduced the amount of wood consumed by *R. virginicus* (Ulyshen and Shelton 2012). *Reticuliternes virginicus* (Banks), treated with sublethal doses of imidacloprid (Premise) it imposes behavioral aversion in them (Thorne and Breisch 2001). Formosan subterranean termites (*Coptotermes formosanus* Shirakii), when provided myo-inositol-2-monophosphate as the dicyclohexylammonium salt. It proves toxic to *C. formosanus* could not consume cellulose food, and died (Grimball et al, 2017). Using RNA-interference

(RNAi) techniques, short-interfering synthesized RNAs (siRNAs) gene injected into worker termites, trail following accuracy is significantly reduced in termites that results in obstruction of feeding behavior (Schwinghammer et al., 2011). In the termite *Reticulitermes flavipes*, the novel gene, named deviate, encodes an apparent ligand binding protein from the takeout-homologous family. Deviate has ubiquitous caste and tissue expression, including antennal expression.

Termite use pheromone for communication purpose and regulate individual behavior with the rest of the colony. Pheromones are discharged in air from external glands. These are produced by the reproductive individuals (queens) and use for establishing and maintaining the dominant reproductive status over hundreds of thousands of workers (Kocher et al., 2011). Sophisticated social behaviors in termite colonies are mainly regulated via chemical communication of a wide range of pheromones. Trail pheromones play important roles in foraging behavior and building tunnels and nests in termites (Gao et al., 2020). Different ant and termite species show variations on the theme of mass communication that likely are associated with the foraging ecology of individual species (James F.A. Traniello et al., 2009).

Sex pheromone is used for couple formation and maintenance, and it is produced by and released from the female sternal gland and is highly attractive to males. (3Z, 6Z) -dodeca-3,6-dien-1-ol is the female sex pheromone of *A. dimorphus* as it evoked the tandem behavior at short distance, and the active quantities ranged from 0.01ng to 10ng. Another compound specific to the female sternal gland is (3Z)-dodec-3-en-1-ol, which show a clear GC-EAD response. The higher amount of (3Z) -dodec-3-en-1-ol (1ng) inhibit the attraction achieved by (3Z, 6Z)-dodeca-3, 6-dien-1-ol. It is used to assess the long-distance attraction, or informing about presence of other colonies using the compound as a trail-following pheromone (Wen et al., 2015). In the black winged subterranean termite, *Odontotermes formosanus* (Shiraki), females secrete the pheromone from their sternal gland to attract males. (Z, Z)-dodeca-3, 6-dien-1-ol and (Z)-dodec-3-en-1-ol, is pheromone sex-pairing pheromone. These compounds act in synergy at long distance, but only (Z, Z)-dodeca-3, 6-dien-1-ol is active at short distance. The pheromone may be useful in efforts to control this pest, which is considered one of the most harmful termite species in the world (Wen et al, 2012). **(Table. 14)**

H. Genetic control of termite

RNA interference (RNAi) is used to target insect pests. The termite *Reticulitermes flavipes* when feed on material containing high-dose double-stranded (ds) RNA, it causes silence of two termite genes: one encoding an endogenous digestive cellulase enzyme and the other a caste-regulatory hexamerin storage protein. Silencing of either gene through dsRNA feeding led to significantly reduced group fitness and mortality (Zhou et al., 2008). Met homolog (ZnMet) expression in heads increased just after the presoldier molt. It reduced by ZnMet double stranded (dsRNA) injection before the presoldier molt (Masuoka et al., 2015). Similarly, inhibition of the cellulase enzyme system is an important approach for termite Coptotermes formosanus (CfEGs). Both dsRNA injection and oral delivery resulted in significant gene silencing of CfEGs and it led to mortality, reduced enzyme activity, and reduced weight compared to control worker termites (Wu et al., 2019).

In addition, transposon Tn5 vector containing genes (tcdA1 and tcdB1) encoding orally insecticidal proteins from the entomopathogenic bacterium *Photorhabdus luminescens* subsp. *laumondii* TT01 is used for termite control (Zhao et al., 2008). Protozoan parasites found in the the hindguts of workers a Formosan subterranean termite, *Coptotermes formosanus* assist in wood digestion (Husseneder et al., 2010). This protozoan parasite is killed by lytic peptides that are also a part of the nonspecific immune system of eukaryotes, and destroy the membranes of microorganisms (Javadpour et al., 1996). Feeding workers of the Formosan subterranean termite genetically engineered yeast strains that express synthetic protozoacidal lytic peptides has been shown to kill the cellulose digesting termite gut protozoa, which results in death of the termite colony (Husseneder et al., 2016). Caste-specific genes regulate antioxidant defense in winged imagoes, nymphs, soldiers and workers of Formosan subterranean termites (Hussain et al., 2017). These could be disturbed by gene knock out use of chemical obstructs (Cristaldo et al., 2015).

I. Hormonal control of termites

Juvenoids and juvenogens found promising candidates for control of pest insect species including termites. Due to the prolonged action of juvenogens, e insect juvenile hormone bioanalog from the juvenogen molecule by means of enzymic systems target insects. Juvenogens are species-targeted structures due to their different physicochemical properties (Wimmer et al., 2006). Polyphenic caste characteristics of termites are hormonally regulated, and juvenile hormone (JH) is particularly involved in caste determination, as is the case with many other social insects (Cornette et al., 2007). Reticulitermes santonensis de Feytaud workers have been provided wood impregnated with a juvenogen, ethyl cis-N-{2-[4-(2-butyryloxycyclohexylmethyl) phenoxy] ethyl} carbamate, labelled with tritium in the benzene ring (305 GBq mmol (-1)). The activity in workers is significantly higher than in pre-soldiers, which had differentiated under the influence of the labelled juvenogen (Tykva et al., 2008).

Juvenogens with fatty acid esters of two parent juvenoid alcohols shows high juvenilizing effect against termite *Prorhinotermes simplex* (Hagen). It causes excessive differentiation of soldiers in a termite colony. Differentiation of excessive soldiers induced by a juvenile hormone-mimicking compound may cause disruption of the social structure and ultimately the death of the colony (Hrdý et al., 2004). In termites, multiple extrinsic factors have been shown to impact caste differentiation. Application of exogenous methoprene a juvenile hormone analog in termites results in irregular termite differentiation. It causes more soldier differentiation in a termite colony. The temperature variation and methoprene treatments on termite cause irregular functions of proteins responsible for differentiation. Specifically, the temperature makes changes in Hexamerin-1, Hexamerin-2, Endo-beta 1, 4 glucanase, and myosin proteins. So, use of juvenile hormone analog could maximize efficiency of termite eradication in the field (Tarver et al., 2012).

J. Modern methods and technological development

For termite control highly specific poison bait formulations are used. These are made after the addition of one attractant a more palatable substance and mixed with poison. These are quite effective in inducing mortality in termites. Termite baiting is now one of the two main management tools in developed countries. It has two main goals: to use small amounts of active ingredient and 'colony elimination', i.e. death of all individuals in the colony (Evans and Iqbal 2015). This unique bait matrix will be available to termites continuously and allows for an annual monitoring interval. The durability of this bait matrix is unprecedented, allowing for bait to remain active for years and thus providing continuous structural protection (Hamm et al., 2013).

a) Control of termites using baits

Chitin synthesis inhibitor (CSI) -baits are sued to kill the colony of *Coptotermes formosanus* Shiraki mainly workers, they stop molting after consuming a lethal dose. The 10-day lag post treatment corresponds to the fasting period during which workers to prepare for ecdysis on the 11th day, at which time mortality occurs due to the effect of CSI (Kakkar and Su 2018). Similarly for controlling colony of *Macrotermes gilvus*, chitin synthesis inhibitors (CSIs) are used with Chlorfluazuron (CFZ) cellulose bait when applied to the population size of termite decrease by 90%, and the queens appeared unhealthy (Lee et al., 2014). In place of chitin synthesis inhibitors, fipronil and imidacloprid could be used potential bait active ingredients against *Macrotermes gilvus* (Hagen). Baits containing imidacloprid show less toicity whereas bait containg fipronil show significant colony elimination (Iqbal and Evans 2018).

Bait formulations containing 250 ppm of the three chitin synthesis inhibitors namely diflubenzuron, hexaflumuron, and chlorfluazuron show significant repellent or feeding deterrent to the termite workers of Formosan subterranean termite, *Coptotermes formosanus* (Rojas and Morales-Ramos 2001). Baits containing two chitinolytic enzyme inhibitors, pentoxifylline and psammaplin show concentration-dependent mortality in *Reticulitermes flavipes* (Kollar). Both chitinase inhibitors are toxic to *R. flavipes*. Concentration-dependent toxicity occurred within the pentoxifylline treatments over the range of 0.01-0.08%, with 0.08% treatments producing an LT50. However, mortality in response to psammaplin A treatments lacked concentration-dependent toxicity (Hiusen and Kamble-Shripat 2013).

Hexaflumuron (0.5% [AI]) baits also reduced termite populations in approximately 2 yr. Adjustments in the specific bait formulations and application procedures might reduce time to suppression. Establishment of new independent termite populations provides a mechanism to minimize the effects of baits (Osbrink et al., 2011). When Bait with Noviflumuron applied to planar area's population of *Coptotermes formosanus*, elimination of baited termite occurred and subsequent reinvasion of the territory by neighboring termites. Territories held by unbaited neighbors termites increased significantly, nearly doubling after reinvasion. Exposed termites are eliminated in large numbers (Bernard et al., 2017).

Table 1: Some latex secreting plants from different families.

Plant family	Plant name	Common name	Reference
Euphorbiaceae	*Hevea brasiliensis*	Rubber tree	Metcalfe et al., 1967
	Euphorbia bicolor	Spurge	Metcalfe et al., 1967
	Synadenium grantii	African milk bush	Metcalfe et al., 1967
	Sapium glandulosum	Gumtree, milktree,	Metcalfe et al., 1967
	Jatropha gossypiifolia	Bellyache bush, black physicnut or cotton-leaf physicnut	Metcalfe et al., 1967
	Hura epitans	Sandbox tree	Metcalfe et al., 1967
	Croton urucurana	Rushfoil and *oton*	Metcalfe et al., 1967
Moraceae	*Ficus carica*	common fig	Metcalfe et al., 1967
	Maclura tinctoria	Old fustic and dyer's mulberry	Metcalfe et al., 1967
	Maclura pomifera	*Osage orange*	Metcalfe et al., 1967
	Brosimum gaudichaudii	Mama Cadela	Metcalfe et al., 1967

	Antiaris toxicaria	Bark cloth tree, antiaris, false iroko, false mvule or upas tree	Metcalfe et al., 1967
	Artocarpus heterophyllus	Jackfruit	Metcalfe et al., 1967
	Dorstenia luamensis	Grendelion or Shield flower	Metcalfe et al., 1967
Apocynaceae	*Nerium oleander*	Kaner, Oleander	Bhadane et al, 2018
	Calotropis procera	King's own	Bhadane et al, 2018
	Thevetia peruviana	Yellow oleander	Bhadane et al, 2018
	Rauvolfia serpentina	Devil peppers, Sarpagandha	Bhadane et al, 2018
	Plumeria rubra	frangipani, red-jasmine	Bhadane et al, 2018
	Catharanthus roseus	Madagascar periwinkle	Bhadane et al, 2018
	Alstonia angustiloba	Blackboard tree or devil's tree	Bhadane et al, 2018
Asteraceae	*Taraxacum koksaghyz*	Kazakh dandelion, rubber root, or Russian dandelion	Bhadane et al, 2018
	Scorzonera latifolia	Viper's grass	Metcalfe et al., 1967
	Lactuca serriola	Prickly lettuce	Metcalfe et al., 1967
	Parthenium argentatum	Guayule	Metcalfe et al., 1967
	Solidago virgaurea	European goldenrod or woundwort	Metcalfe et al., 1967
	Artemisia annua	Sweet sagewort	Metcalfe et al., 1967
Cannabaceae	*Cannabis sativa*	Charas; ganja, marijuana, dagga, maconha	Metcalfe et al., 1967
	Humulus lupulus	Common hop	Metcalfe et al., 1967

Table 2: Some common latex producing plants from family apocynaceae.

Scienctific name	Common name	Reference
Allamanda cathartica	Golden trumpet	Bhadane et al 2018
Alstonia angustiloba	Blackboard tree or devil's tree	Bhadane et al 2018
Calotropis procera	Apple of Sodom, Sodom apple, stabragh, king's own, rubber bush, and rubber tree	Bhadane et al 2018
Catharanthus roseus	Bright eyes, Cape periwinkle, graveyard plant, Madagascar periwinkle, old maid, pink periwinkle, rose periwinkle	Bhadane et al 2018
Cerbera floribunda,	Sea mango	Bhadane et al 2018
Dyera costulata	Jelutong	Bhadane et al 2018
Nerium oleander	Kaner, Oleander, Rosebay, Rose Laurel	Bhadane et al 2018
Plumeria alba	White Frangipani	Bhadane et al 2018
Vallaris glabra	Bread Flower, Siku Dengan, Bunga Tongkan, Kerak Nasi, Bunga Kesidang, Kesedengan	Bhadane et al 2018
Hancornia speciosa	Mangabeira	Bhadane et al 2018
Acokanthera oblongifolia	African wintersweet, dune poison bush, Hottentot's poison, poison arrow plant or wintersweet	Bhadane et al 2018
Apocynum cannabinum	dogbane, amy root, hemp dogbane, prairie dogbane, Indian hemp, rheumatism root, or wild cotton	Bhadane et al 2018
Thevetia peruviana	Yellow oleander, be still tree, digoxin, lucky nut, yellow bells	Bhadane et al 2018

Rauvolfia serpentina	Devil peppers, Sarpagandha	Bhadane et al 2018
Plumeria rubra	frangipani, red paucipan, red-jasmine, red frangipani, common frangipani, temple tree	Bhadane et al 2018
Tabernaemontana divaricata	*Pinwheel flower*, *ape jasmine*, East India rosebay and Nero's own	Bhadane et al 2018
Himatanthus drasticus	Janaguba	Bhadane et al 2018

Table 3: Cardenolide from latex of different plants (apocynaceae).

Plant name	Cardenolide	Biological effect	References
Acokanthera oblongifolia	acovenosigenin A 3-*O*-*α*-L-acofriopyranoside	Anti-feedent	Pecio et al, 2019
	14-anhydroacovenosigenin A 3-*O*-[*β*-D-glucopyranosyl-(1″→4')-*O*-*α*-L-acofriopyranoside]	Anti-feedent	Pecio et al, 2019
	14-anhydroacovenosigenin A 3-*O*-[*β*-D-glucopyranosyl-(1″→4')-*O*-*α*-L-acovenopyranoside]	Anti-feedent	Pecio et al, 2019
	14-anhydrodigitoxigenin 3-*O*-*β*-D-glucopyranoside acospectoside A	Anti-feedent	Pecio et al, 2019
Calotropis procera	Ischarin	Anti-termitic activity	Sweidan et al, 2015
	Ischaridin	Anti-termitic activity	Sweidan et al, 2015
Cerbera odollam	Cerberin	Toxic to termites	Menezes et al, 2018
Nerium indicum	3beta-O-(beta-D-diginosyl)-14,15alpha-dihydroxy-5alpha- card-20(22)-enolide (1)	Nematicidal, termicidal	Wang et al, 2009
	Uzarigenin	Termicidal	Wang et al, 2009
	Cardenolide N-1	Termicidal	Wang et al, 2009
Calotropis gigantea	15beta-hydroxycardenolides	Cell activity inhibitor	Seeka et al, 2010
	16alpha-hydroxycalactinic acid methyl ester		
Pergularia tomentosa	6'-hydroxy-16alpha-acetoxycalactin	Cytotoxic: inhibitor of Na+/K+-ATPase	Piacente et al, 2009
Asclepias curassavica	12beta,14beta-dihydroxy-3beta,19-epoxy-3alpha-methoxy-5alpha-card-20(22)-enolide 12beta-hydroxycalotropin	Cytotoxic activity against HepG2 and Raji cell lines	Li et al, 2009

Table 4: Some alkaloids from the plants of apocynaceae.

Plant name	Alkaloids	Biological effect	References
Rauvolfia vomitoria	Rauvomitorine A-I C-9-methoxymethylene-sarpagine	acetylcholinesterase inhibitory (AChE) activities	Zhan et al, 2020
Melodinus axillaris	Melotenine A aspidosperma	Cytotoxic against termites	Fang et al, 2019
Tabernaemontana bufalina	Taberhaines	Inhibitor of xanthine oxidase	Shi et al, 2019
Melodinus henryi	Melodinhenenes A-F melodinines	Anti-termite Cytotoxic	Ke Ma et al, 2014 and He et al, 2019
Tabernaemontana divaricata	Taberniacins A and B	vasorelaxant activity	Hirasawa et al, 2019
Melodinus tenuicaudatus	melotenuines A-E	cytotoxic	Liu et al, 2019
Leuconotis eugeniifolia	Leucophyllinines A and B	antiplasmodial activities and toxic to termites	Tang Y et al, 2019

Table 5: Cystein peptidases in the latex of some plants (apocynaceae).

Plant name	Cystein Peptidases	Biological effects	References
Calotropis procera	CpCP1, CpCP2, and CpCP3	Anti-fungal: promoted membrane permeabilization, morphological changes with leakage of cellular content, and induction of ROS	Freitas et al, 2020
Araujia angustifolia	Araujiain	Proteolytic activity	Obregón et al, 2011
Cryptostegia grandiflora	Cg24-I	Toxic against phytopathogens	Ramos et al, 2014
Asclepias subulata	12, 16-dihydroxicalotropin, calotropin, corotoxigenin 3-O-glucopyranoside and desglucouzarin	Cell death trough caspase-dependent apoptosis	Rascón-Valenzuela et al, 2016
Philibertia gilliesii	philibertain g I	Proteolytic activity	Sequeiros et al, 2010
Thevetia peruviana	peruvianin-I	Exhibit high specific activity towards azocasein	de Freitas et al, 2016
Asclepias curasavica	Calotropin	Exert strong inhibitory and pro-apoptotic activity	Mo et al, 2016
Dregea sinensis	procerain B	Degrade α-casein (CN)	Zhang et al, 2015
Ervatamia coronaria	Ervatamin-A, ervatamin-B and ervatamin-C.	Anti-termitic	Ghosh et al, 2008

Table 6: Some Flavonoids from different plants (apocynaceae).

Plant name	Flavonoids	Biological effects	References
Apocynum venetum	plumbocatechin A , 8-O-methylretusin and kaempferol 3-O-(6″-O-acetyl)-β-D-galactopyranoside	Antimicrobial activity toxic to termites	Kong et al, 2014
Holarrhena floribunda	Kaemperol-3-O-rutinoside , quercetin-3-O-glucoside and kaemperol-3-O-glucoside	Antioxidant activity	Badmus et al, 2016
Vinca minor	Kaempferol 3-rhamnogluco-7-glucoside , kaempferol 3-rhamnogluco-7-galactoside, quercetin 3-rutino-7-glucoside and quercetin 3-rhamnogluco-7-glucoside	Termicidal	Szostak et al, 1975
Cynanchum acutum	Kaempferol-3-O-β-xylopyranosyl-(1-2)-β-rhamnopyranoside, quercetin-3-O-β-xyloside, kaempferol-3-O-β-glucosid , quercetin-3-O-β-glucoside, kaempferol-3-O-β-rhamnopyranoside and kaempferol-3-O-β-d-neohesperidoside	Antiproliferative effects	Yildiz et al, 2017
Echites hirsuta	Naringenin, aromadendrin (dihydrokaempferol) and kaempferol	Termicidal	Chien et al, 1979
Trachelospemum jasminoides	Apigenin, apigenin 7-O-beta-glucoside, apigenin 7-O-beta-neospheroside, narngin and 6,8-di-C-glucopyanosylapigenin	Anti-feedent	Tan et al, 2010

Table 7: Terpenes found in apocynaceae members.

Plant name	Terpenes	Biological effects	References
Periploca somaliensis	Perisomalien A, lupeol acetate, *β*-amyrin cycloart-23Z-ene-3β,25-diol, and *β*-sitosterol-3-*O*-*β*-D-glucopyranoside	Toxic effects	Jabal et al, 2020
Epigunum griffithianum	Saponin epigynosides A and B	immunosuppressive activities	Wang et al, 2020
Gymnema sylvestre	Saponins	Anti-microbial	Fabio et al, 2014
Pleiocarpa pycnantha	ursolic acid	cytotoxic activity	Omoyeni et al, 2014
Pentalinon andrieuxii	urechitol A	Anti-feedent	Hiebert-Giesbrecht et al, 2016

Table 8: Some Sterols from apocynaceae family.

Plant name	Sterols	Biological effects	References
Pentalinon andrieuxii	Pentalinonside, pentalinonsterol	antileishmanial activity	Pan et al, 2012
Alstonia scholaris	poriferasterol, epicampesterol, β-sitosterol, 6β-hydroxy-4-stigmasten-3-one, and ergosta-7,22-diene-3β,5α,6β-triol	anti-proliferative activity	Wang et al, 2017
Gymnema sylvestre	beta-sitosterol, campesterol and stigmasterol	Anti-feedent	Vats et al, 2013
Cynanchum limprichtii	limproside A and limproside B	Cytotoxic	Liu et al, 2018
Periploca forrestii	β-sitosterol and β-daucosterol	Cytotoxic	Zhang et al, 2016
Pergularia tomentosa	3-acetyltaraxasterol, 3-taraxasterol and 16α-hydroxytaraxasterol-3-acetate	Toxic to termites	Babaamer et al, 2012

Table 9: Phenolic compounds from apocynaceae members.

Plant name	Phenol compound	Biological effects	References
Hancornia speciosa	Protocatechuic acid, catechin, and quercetin	Detterent	Bastos et al, 2017
Asclepias linaria	*p*-coumaric and ferulic acid,	Antioxidant and cytotoxic activities	Sánchez-Gutiérrez et al, 2019
Carissa macrocarpa	Phenolic acids	Antimicrobial activities	Souilem et al, 2019
Cynanchum wilfordii	2-*O*-β-laminaribiosyl-4-hydroxyacetophenone	Termicidal	Uchikura et al, 2018

Table 10: Lignans from the member of family apocynaceae.

Plant name	Lignan	Biological effect	Reference
Calotropis gigantea	(+)-pinoresinol 4-O-[6″-O-vanilloyl]-β-d-glucopyranoside	Insecticidal	Parhira et al, 2014
Carissa carandas	reveledcarinol	Insecticidal	Pal et al, 1975
	6R,7S,8S)-7a-[(b-glucopyranosyl) oxy]lyoniresinol	Insecticidal	Bhadane et al, 2018
	carissanol	Insecticidal	Bhadane et al, 2018
	(-)-nortrachelogenin	Insecticidal	Bhadane et al, 2018

Table 11: Some chemical used in termite control.

Chemical name	Concentration	Used against	Effect	References
2,4-D amine salt (2,4-D)	-----	*Macrotermes bellicosus*	Toxic	Ejomah et al, 2020
Vestamine and Ultrazine	------		Toxic	Ejomah et al, 2020
Fipronil	0-64 ppm		Neurotoxic	Iqbal et al, 2018
Imidacloprid	0-250 ppm		Neurotoxic	Iqbal et al, 2018
Chlorantraniliprole	5-ppm	*Reticulitermes flavipes*	Anti-feedent	Buczkowski et al, 2012
1,4-dichlorobenzene	------		Anti-feedent	Morita et al, 1977
Silafluofen	------		soil termiticide	Katsuda et al, 2011
Bifenthrin	1.25 µg cm^2		Highly toxic	Guan et al, 2011
Chitosan solutions	38 mg g^{-1}		Highly toxic	Raji et al, 2018
Mancozeb	100 g/L		Anti-feedent	Brandford et al, 2019
Lambda cyhalothrin	4 ml/L		Anti-feedent	Brandford et al, 2019
Chlorpyrifos	10 mg/kg soil	*Coptotermes formosanus*	Toxic	Das et al, 2015
Chlordane			Toxic	Phillips et al, 2010
Spinosad	50 ppm		Toxic	Bhatta et al, 2016

Table 12: Some Natural enemies of termites.

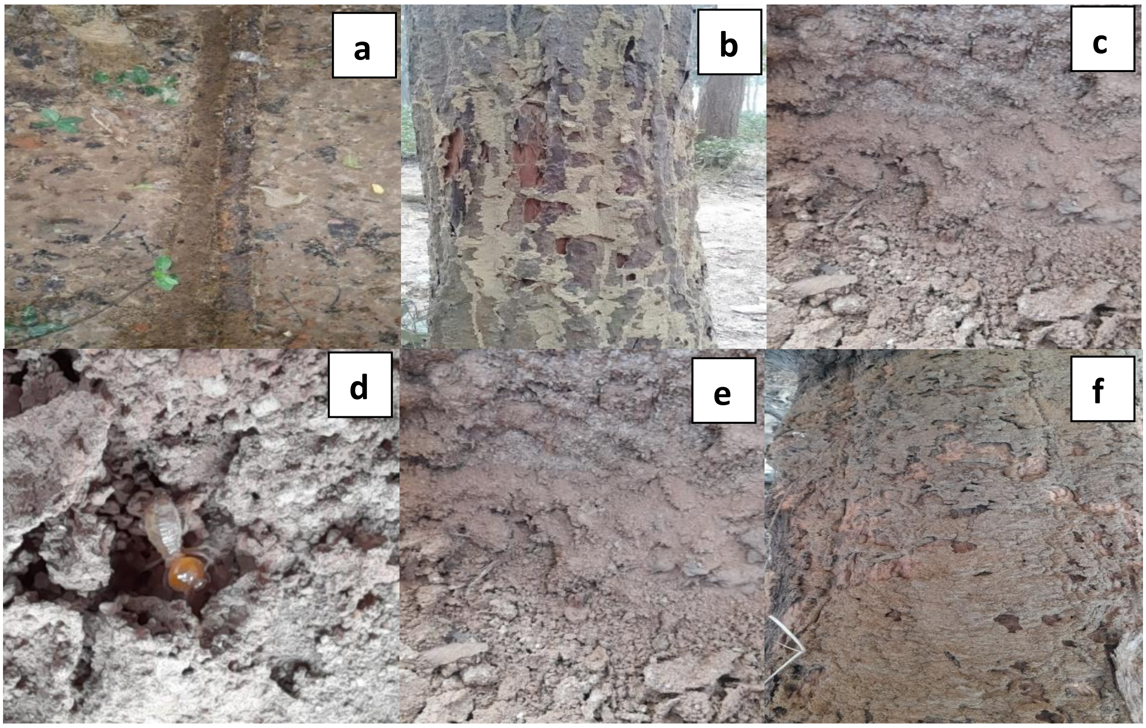
Natural enemy	Categories	References
Oogpister Beetle, Ants, Assassin bugs, Flies, Spiders and Wasps	Insects	Culliney et al., 2000
Red-Headed Woodpecker, Chickens, Doves, Sparrows, Spotted Eagle Owls, Starlings, Swifts, Weavers and Egyptian goose (Alopochen Aegyptiacus)	Birds	Sahayaraj et al., 2018
Geckos, Lizards and Snakes	Reptiles	Sahayaraj et al., 2018
Frogs	Amphibians	Sahayaraj et al., 2018
Aardvarks, Anteaters, Armadillos, Bats and Primates	Mammals	Sahayaraj et al., 2018

Table 13: Microbes in termite control.

Microbe category	Name	Used against	Biological effects	References
Fungi	*Isaria fumosorosea*	*Coptotermes formosanus*	Produce infectious conidia	Maureen Wright et al 2012
	Metarhizium anisopliae	*Coptotermes formosanus*	Alarm, aggregation and defensive reactions, repellent	Maureen Wright et al 2012
	Beauveria bassiana	*Reticulitermes flavipes*	Infectious	Wright et al, 2013
	Fusarium	*Reticulitermes flavipes*	Produce infectious conidia	Teetor-Barsch et al, 1983
Bacteria	*Bacillus thuringiensis*	*Coptotermes formosanus*	Produce infectious propagules	Wright et al 2012
	Trabulsiella odontotermitis	*Coptotermes formosanus*	Spreading gene products in termite	Tikhe et al 2016
	Photorhabdus luminescens	*Coptotermes formosanus*	Express termicidal genes	Zhao et al, 2008
Nematodes	*Heterorhabditis bacteriophora*	*Microcerotermes diversus*	Pathogenic to termites	Al-Zaidawi et al, 2020
	H. bacteriophora Poinar (IRQ.1 strain)	*Microcerotermes diversus*	Pathogenic to termites	Al-Zaidawi et al, 2020
	Steinernema carpocapsae	*Microcerotermes diversus*	Pathogenic to termites	Al-Zaidawi et al, 2020
	Heterorhabditis bacteriophora Poinar (HP88 strain)	*Heterotermes aureus* (Snyder), *Gnathamitermes perplexus* (Banks), and *Reticulitermes flavipes* (Kollar)	infect and kill termites	Yu et al, 2006
	Termirhabditis fastidiosus	*Reticulitermes flavipes* and *Coptotermes*	Kill protozoan symbionts in termites gut	Massey et al., 1971
	Rhabpanus ossiculum	*Reticulitermes flavipes* and *Coptotermes*	Kill protozoan symbionts in termites gut	Massey et al., 1971
	Steinernema riobrave strain 355	*Heterotermes aureus*, *Reticulitermes flavipes*, and *Coptotermes formosanus.*	virulence to termites	Yu et al, 2010

Table 14: Pheromones used by termites in communication.

Pheromones	Producing gland	Termite species	Pheromone category	Role	References
(3Z,6Z)-dodeca-3,6-dien-1-ol	Female tergal gland	*Silvestritermes heyeri, S. minutes,*	Sex pheromone	Attract males, elicits, Trail-following behavior	Dolejšová et al, 2018 Wen et al, 2015
	Female sternal gland	*Odontotermes formosanus*			
(3Z)-dodec-3-en-1-ol	Female tergal gland	*Silvestritermes minutus*	Sex pheromone	Enhance the long-distance attraction of male at higher cocentration	Dolejšová et al, 2018 Wen et al, 2015
	Female sternal gland	*Odontotermes formosanus*			
(3Z,6Z,8E)-dodeca-3,6,8-trien-1-ol	Female tergal glands	*E. neotenicus*	Sex pheromone	Pairing hormone	Dolejšová et al, 2018,
	Alates and female sternal gland	*Reticulitermes lucifugus grassei and R. santonensis*	trail-following and sex pheromone	Pairing hormone	Wobst, et al, 1999
		Cornitermes bequaerti, C. cumulans and C. silvestrii	trail-following and sex pheromone	species-specific pairing	Bordereau et al, 2011
syn-4,6-dimethylundecan-1-ol	Male sternal gland	*Hodotermopsis sjoestedti, Zootermopsis nevadensis and Zootermopsis angusticollis*	Trail-following and Sex pheromone	Pairing	Lacey et al, 2011
(5E)-2,6,10-trimethylundeca-5,9-dienal	Female sternal gland	*Hodotermopsis sjoestedti, Zootermopsis nevadensis*	Sex pheromone	Pairing	Lacey et al, 2011
Norsesquiterpene alcohol (E)-2,6,10-trimethyl-5,9-undecadien-1-ol	Male and female sternal gland	*Mastotermes darwiniensis*	Trail pheromone	Trail following	Sillam-Dussès et al, 2007



Photograph 1: (a-f) showing plastering of green trees, termite worker inside mound, invaded tree, green biomass and digested soil.

3. CONCLUSION

This article emphasizes use of various plant latexes as insecticides to control forest, household and garden termite population. Latex components show multiple deleterious effects like toxic, anti-feedant, repellent growth and reproductive inhibitory in a number of insect species. It delays egg maturation, development and inhibit gonad development in insects. Besides this, toxic microbial metabolites, whole organisms, feeding inhibitor chemical synthesize genus, radiations for chromosomal damage, essential oils, growth inhibitors, hormone analogues can be used for potential control of agricultural, household and garden termite population. In addition, Juvenoids and juvenogens considered to be promising method for control of termites. Make them more active and selector as antifeedent, repellent, fumigant or bait formulation as well. Feeding in workers of termite species could be withheld by using genetically engineered yeast strains that express synthetic protozoacidal lytic pepdies. These early kill the cellulose digesting termite gut protozoa that result in mass mortality of termite colony members. Employment and release of natural enemies of termite also safe method for controling them. Plant derived natural products are easily catabolized in nature, show less side-effects, do not present for longer time and do not kill non-targated organisms. Due to the rising toxicity of synthetic pesticides in agriculture soil and its biomagnfication there pesticides have been fully banned. Therefore, this article suggests use of natural control methods, so that poisoning of food chains and problem of biomagnifications and toxicity could be minimized.

REFERENCES

1. Ahmad F, Fouad H, Liang SY, Hu Y, Mo JC. Termites and Chinese agricultural system: applications and advances in integrated termite management and chemical control. Insect Sci., 2021; 28(1): 2-20.
2. Scully ED, Hoover K, Carlson JE, Tien M, Geib SM. Midgut transcriptome profiling of *Anoplophora glabripennis*, a lignocellulose degrading cerambycid beetle. BMC Genomics, 2013; 14(1): 850.
3. Culliney TW, Grace JK. Prospects for the biological control of subterranean termites (Isoptera: rhinotermitidae), with special reference to *Coptotermes formosanus*. Bull Entomol Res., 2000; 90(1): 9-21.
4. Paul, Bishwajeet, Khan, Md & Paul, Sangeeta & Shankarganesh, Karuppan & Chakravorty, Sarbashish. Termites and Indian Agriculture, 2018; 10.1007/978-3-319-68726-1_3.
5. Zorzenon FJ, Campos AE. Subterranean termites in urban forestry: tree preference and management. Neotrop Entomol, 2015; 44(2): 180-5.
6. Sun Q, Hampton JD, Merchant A, Haynes KF, Zhou X. Cooperative policing behaviour regulates reproductive division of labour in a termite. Proc Biol Sci., 2020; 287(1928): 20200780.
7. Cosme L Jr, Haro MM, Guedes NMP, Della Lucia TMC, Guedes RNC. Tropical wood resistance to the West Indian drywood termite *yptotermes brevis*: If termites can't chew…. Pest Manag Sci., 2018; 74(4): 914-924.
8. Cornelius ML, Osbrink WL. Effect of seasonal changes in soil temperature and moisture on wood consumption and foraging activity of Formosan subterranean termite (Isoptera: Rhinotermitidae). J Econ Entomol, 2011; 104(3): 1024-30.
9. Cornelius ML, Osbrink WL. Bioassay design and length of time in the laboratory affect intercolonial interactions of the Formosan subterranean termite (Isoptera, Rhinotermitidae). Insectes Soc., 2009; 56(2): 203-211.
10. Veldhuis MP, Laso FJ, Olff H, Berg MP. Termites promote resistance of decomposition to spatiotemporal variability in rainfall. Ecology, 2017; 98(2): 467-477.

11. Cornelius ML, Osbrink WL, Gallatin EM. Seasonal Changes in the Caste Distribution of Foraging Populations of Formosan Subterranean Termite in New Orleans, Louisiana. J Insect Sci., 2015; 15(1): 115.
12. Xie Y, Huang Q, Lei C. Bioassay-guided isolation and identification of antitermitic active compound from the leaf of Chinese cedar (*Cryptomeria fortunei* Hooibrenk). Nat Prod Res., 2013; 27(22): 2137-9.
13. Srivani Maddala VK. Green pest management practices for sustainable buildings: itical review. Sci Prog., 2019; 102(2): 141-152.
14. Livshultz T, Kaltenegger E, Straub SCK, Weitemier K, Hirsch E, Koval K, Mema L, Liston A. Evolution of pyrrolizidine alkaloid biosynthesis in Apocynaceae: revisiting the defence de-escalation hypothesis. New Phytol, 2018; 218(2): 762-773.
15. Ernst M, Nothias LF, van der Hooft JJJ, Silva RR, Saslis-Lagoudakis CH, Grace OM, Martinez-Swatson K, Hassemer G, Funez LA, Simonsen HT, Medema MH, Staerk D, Nilsson N, Lovato P, Dorrestein PC, Rønsted N. Assessing Specialized Metabolite Diversity in the Cosmopolitan Plant Genus *Euphorbia* L. Front Plant Sci., 2019; 10: 846.
16. Szabó LF. Diversity and selectivity in biomolecules. Acta Pharm Hung, 2001; 71(4): 392-404.
17. Araya JJ, Binns F, Kindscher K, Timmermann BN. Verticillosides A-M: Polyoxygenated pregnane glycosides from *Asclepias verticillata* L. Phytochemistry, 2012; 78: 179-89.
18. Runguphan W, Maresh JJ, O'Connor SE. Silencing of tryptamine biosynthesis for production of nonnatural alkaloids in plant culture. Proc Natl Acad Sci U S A., 2009; 106(33): 13673-8.
19. Rasmann S, Agrawal AA. Latitudinal patterns in plant defense: evolution of cardenolides, their toxicity and induction following herbivory. Ecol Lett., 2011; 14(5): 476-83.
20. Deng AJ, Yu JQ, Li ZH, Ma L, Zhang ZH, Qin HL. 14, 15-Secopregnane-Type Glycosides with 5α:9α-Peroxy and $\Delta^{6,8(14)}$-diene Linkages from the Roots of *Cynanchum stauntonii*. Molecules, 2017; 22(6): 860.
21. Zhang DB, Yu DG, Sun M, Zhu XX, Yao XJ, Zhou SY, Chen JJ, Gao K. Ervatamines A-I, Anti-inflammatory Monoterpenoid Indole Alkaloids with Diverse Skeletons from *Ervatamia hainanensis*. J Nat Prod., 2015; 78(6): 1253-61.
22. Stavrinides A, Tatsis EC, Foureau E, Caputi L, Kellner F, Courdavault V, O'Connor SE. Unlocking the diversity of alkaloids in *Catharanthus roseus*: nuclear localization suggests metabolic channeling in secondary metabolism. Chem Biol., 2015; 22(3): 336-41.

23. Dang TT, Franke J, Tatsis E, O'Connor SE. Dual Catalytic Activity of a Cytochrome P450 Controls Bifurcation at a Metabolic Branch Point of Alkaloid Biosynthesis in *Rauwolfia serpentina*. Angew Chem Int Ed Engl, 2017; 56(32): 9440-9444.
24. Zeb A, Ullah F, Ayaz M, Ahmad S, Sadiq A. Demonstration of biological activities of extracts from *Isodon rugosus* Wall. Ex Benth: Separation and identification of bioactive phytoconstituents by GC-MS analysis in the ethyl acetate extract. BMC Complement Altern Med., 2017; 17(1): 284.
25. Ganapaty S, Thomas PS, Fotso S, Laatsch H. Antitermitic quinones from *Diospyros sylvatica*. Phytochemistry, 2004; 65(9): 1265-71.
26. Meepagala KM, Osbrink W, Burandt C, Lax A, Duke SO. Natural-product-based chromenes as a novel class of potential termiticides. Pest Manag Sci., 2011; 67(11): 1446-50.
27. Abdullah F, Subramanian P, Ibrahim H, Abdul Malek SN, Lee GS, Hong SL. Chemical composition, antifeedant, repellent, and toxicity activities of the rhizomes of galangal, *Alpinia galanga* against Asian subterranean termites, *Coptotermes gestroi* and *Coptotermes curvignathus* (Isoptera: Rhinotermitidae). J Insect Sci., 2015; 15(1): 175.
28. Meepagala KM, Osbrink W, Sturtz G, Lax A. Plant-derived natural products exhibiting activity against formosan subterranean termites (*Coptotermes formosanus*). Pest Manag Sci., 2006; 62(6): 565-70.
29. Könczöl A, Müller J, Földes E, Béni Z, Végh K, Kéry A, Balogh GT. Applicability of a blood-brain barrier specific artificial membrane permeability assay at the early stage of natural product-based CNS drug discovery. J Nat Prod., 2013; 76(4): 655-63.
30. Schrader KK, Andolfi A, Cantrell CL, Cimmino A, Duke SO, Osbrink W, Wedge DE, Evidente A. A survey of phytotoxic microbial and plant metabolites as potential natural products for pest management. Chem Biodivers, 2010; 7(9): 2261-80.
31. Bernard K, Groden E, Drummond FA. Evaluation of Four Plant Extract Repellents for Management of the European Red Ant *Myrmica rubra* (Hymenoptera: Formicidae). J Econ Entomol, 2020; 113(4): 1609-1617.
32. Asadollahi A, Khoobdel M, Zahraei-Ramazani A, Azarmi S, Mosawi SH. Effectiveness of plant-based repellents against different *Anopheles* species: a systematic review. Malar J., 2019; 18(1): 436.
33. Bläske VU, Hertel H. Repellent and toxic effects of plant extracts on subterranean termites (Isoptera: Rhinotermitidae). J Econ Entomol, 2001; 94(5): 1200-8.

34. Hassan B, Ahmed S, Kirker G, Mankowski ME, Misbah Ul Haq M. Synergistic effect of heartwood extracts in combination with linseed oil as wood preservatives against subterranean termite *Heterotermes indicola* (Blattodea: Rhinotermitidae). Environ Sci Pollut Res Int., 2020; 27(3): 3076-3085.
35. Hassan B, Mankowski ME, Kirker GT, Clausen CA, Ahmed S. Effects of White Mulberry (*Morus alba*) Heartwood Extract Against *Reticulitermes flavipes* (Blattodea: Rhinotermitidae). J Econ Entomol, 2018; 111(3): 1337-1345.
36. Cheng SS, Lin CY, Chen YJ, Chung MJ, Chang ST. Insecticidal activities of *Cunninghamia konishii* Hayata against Formosan subterranean termite, *Coptotermes formosanus* (Isoptera: Rhinotermitidae). Pest Manag Sci., 2014; 70(8): 1215-9.
37. Yuan Z, Hu XP. Repellent, antifeedant, and toxic activities of *Lantana camara* leaf extract against *Reticulitermes flavipes* (Isoptera: Rhinotermitidae). J Econ Entomol, 2012; 105(6): 2115-21.
38. KinyaKinyanjui T, Gitu PM, Kamau GN. Potential antitermite compounds from *Juniperus procera* extracts. Chemosphere, 2000; 41(7): 1071-4.
39. Mukandiwa L, Naidoo V, Katerere DR. The use of *Clausena anisata* in insect pest control in Africa: A review. J Ethnopharmacol, 2016; 194: 1103-1111.
40. Bakaruddin NH, Ab Majid AH. Efficacy of Several Plants Extracts on the Tunneling Activity and Survival of Subterranean Termites (*Coptotermes gestroi* and *Globitermes sulphureus*). Trop Life Sci Res., 2019; 30(1): 33-56.
41. Alavijeh, E.H., Habibpour, B., Moharrabipour, S., Rasekh, A. Bioactivity of *Eucalyptus camaldulensis* essential oil against *Microcerotermes diversus* (Isoptera: Termitidae). J. op Prot., 2014; 3: 1–11.
42. Aziz ZAA, Ahmad A, Setapar SHM, Karakucuk A, Azim MM, Lokhat D, Rafatullah M, Ganash M, Kamal MA, Ashraf GM. Essential Oils: Extraction Techniques, Pharmaceutical And Therapeutic Potential - A Review. Curr Drug Metab, 2018; 19(13): 1100-1110.
43. Bakkali F, Averbeck S, Averbeck D, Idaomar M. Biological effects of essential oils--a review. Food Chem Toxicol, 2008; 46(2): 446-75.
44. Santos AA, de Oliveira BMS, Melo , Lima APS, Santana EDR, Blank AF, Picanço MC, Araújo APA, istaldo PF, Bacci L. Sub-lethal effects of essential oil of *Lippia sidoides* on drywood termite *yptotermes brevis* (Blattodea: Termitoidea). Ecotoxicol Environ Saf., 2017; 145: 436-441.

45. Zhu BC, Henderson G, Chen F, Maistrello L, Laine RA. Nootkatone is a repellent for Formosan subterranean termite (*Coptotermes formosanus*). J Chem Ecol, 2001; 27(3): 523-31.
46. Maistrello L, Henderson G, Laine RA. Efficacy of vetiver oil and nootkatone as soil barriers against Formosan subterranean termite (Isoptera: Rhinotermitidae). J Econ Entomol, 2001; 94(6): 1532-7.
47. Raina A, Bland J, Doolittle M, Lax A, Boopathy R, Folkins M. Effect of orange oil extract on the formosan subterranean termite (Isoptera: Rhinotermitidae). J Econ Entomol, 2007; 100(3): 880-5.
48. Acda MN. Toxicity, tunneling and feeding behavior of the termite, *Coptotermes vastator*, in sand treated with oil of the physic nut, *Jatropha curcas*. J Insect Sci., 2009; 9: 1-8.
49. Huber M, Epping J, Schulze Gronover C, Fricke J, Aziz Z, Brillatz T, Swyers M, Köllner TG, Vogel H, Hammerbacher A, Triebwasser-Freese D, Robert CA, Verhoeven K, Preite V, Gershenzon J, Erb M. A Latex Metabolite Benefits Plant Fitness under Root Herbivore Attack. PLoS Biol., 2016; 14(1): e1002332.
50. Ramos MV, Demarco D, da Costa Souza IC, de Freitas CDT. Laticifers, Latex, and Their Role in Plant Defense. Trends Plant Sci., 2019; 24(6): 553-567.
51. Agrawal AA, Hastings AP. Plant Defense by Latex: Ecological Genetics of Inducibility in the Milkweeds and a General Review of Mechanisms, Evolution, and Implications for Agriculture. J Chem Ecol, 2019; 45(11-12): 1004-1018.
52. Sytwala S, Domsalla A, Melzig MF. Investigation of plant latices of Asteraceae and Campanulaceae regarding proteolytic activity. Plant Physiol Biochem, 2015; 97: 117-23.
53. Lewinsohn T. The geographical distribution of plant latex. Chemoecology, 1991; 2: 64-68. 10.1007/BF01240668.
54. Metcalfe . Distribution of latex in the plant kingdom. Econ Bot., 1967; 21: 115–127.
55. Chan EW, Wong SK, Chan HT. Apocynaceae species with antiproliferative and/or antiplasmodial properties: a review of ten genera. J Integr Med., 2016; 14(4): 269-84.
56. Wu QC, Tang YP, Ding AW, You FQ, Zhang L, Duan JA. 13C-NMR data of three important diterpenes isolated from *Euphorbia* species. Molecules, 2009; 14(11): 4454-75.
57. Bhadane , Patil MP, Maheshwari VL, Patil RH. Ethnopharmacology, phytochemistry, and biotechnological advances of family Apocynaceae: A review. Phytother Res., 2018; 32(7): 1181-1210.
58. Hagel JM, Yeung EC, Facchini PJ. Got milk? The secret life of laticifers. Trends Plant Sci., 2008; 13(12): 631-9.

59. Dussourd DE, Van Valkenburg M, Rajan K, Wagner DL. A notodontid novelty: *Theroa zethus* caterpillars use behavior and anti-predator weaponry to disarm host plants. PLoS One, 2019; 14(7): e0218994.
60. Rosa SSRF, Rosa MFF, Fonseca MAM, Luz GVDS, Avila CFD, Domínguez AGD, Dantas AGD, Richter VB. Evidence in Practice of Tissue Healing with Latex Biomembrane: Integrative Review. J Diabetes Res. 2019; 2019: 7457295.
61. Tasca JA, Smith , Burzynski EA, Sundberg BN, Lagalante AF, Livshultz T, Minbiole KPC. HPLC-MS detection of pyrrolizidine alkaloids and their *N*-oxides in herbarium specimens dating back to the 1850s. Appl Plant Sci., 2018; 6(4): e1143.
62. Cristina RT, Dumitrescu E, Brezovan D, Muselin F, Chiurciu V. Effect of *Euphorbia cyparissias* ointments on acanthosis. Afr J Tradit Complement Altern Med., 2014; 11(3): 1-6.
63. Sibi G, Wadhavan R, Singh S, Shukla A, Dhananjaya K, Ravikumar KR, Mallesha H. Plant latex: a promising antifungal agent for post harvest disease control. Pak J Biol Sci., 2013; 16(23): 1737-43.
64. Konno K. Plant latex and other exudates as plant defense systems: roles of various defense chemicals and proteins contained therein. Phytochemistry, 2011; 72(13): 1510-30.
65. Salomé Abarca LF, Klinkhamer PGL, Choi YH. Plant Latex, from Ecological Interests to Bioactive Chemical Resources. Planta Med., 2019; 85(11-12): 856-868.
66. Agrawal AA, Petschenka G, Bingham RA, Weber MG, Rasmann S. Toxic cardenolides: chemical ecology and coevolution of specialized plant-herbivore interactions. New Phytol, 2012; 194(1): 28-45.
67. Wen S, Chen Y, Lu Y, Wang Y, Ding L, Jiang M. Cardenolides from the Apocynaceae family and their anticancer activity. Fitoterapia, 2016; 112: 74-84.
68. Züst T, Petschenka G, Hastings AP, Agrawal AA. Toxicity of Milkweed Leaves and Latex: Chromatographic Quantification versus Biological Activity of Cardenolides in 16 *Asclepias* Species. J Chem Ecol, 2019; 45(1): 50-60.
69. Rasmann S, Agrawal AA, Cook SC, Erwin AC. Cardenolides, induced responses, and interactions between above- and belowground herbivores of milkweed (*Asclepias* spp.). Ecology, 2009; 90(9): 2393-404.
70. Dobler S, Petschenka G, Pankoke H. Coping with toxic plant compounds--the insect's perspective on iridoid glycosides and cardenolides. Phytochemistry, 2011; 72(13): 1593-604.

71. El-Seedi HR, Khalifa SAM, Taher EA, Farag MA, Saeed A, Gamal M, Hegazy MF, Youssef D, Musharraf SG, Alajlani MM, Xiao J, Efferth T. Cardenolides: Insights from chemical structure and pharmacological utility. Pharmacol Res., 2019; 141: 123-175.
72. Pecio Ł, Hassan EM, Omer EA, Gajek G, Kontek R, Sobieraj A, Stochmal A, Oleszek W. Cytotoxic Cardenolides from the Leaves of *Acokanthera oblongifolia*. Planta Med., 2019; 85(11-12): 965-972.
73. Sweidan NI, Abu Zarga MH. Two novel cardenolides from *Calotropis procera*. J Asian Nat Prod Res., 2015; 17(9): 900-7.
74. Menezes RG, Usman MS, Hussain SA, Madadin M, Siddiqi TJ, Fatima H, Ram P, Pasha SB, Senthilkumaran S, Fatima TQ, Luis SA. *Cerbera odollam* toxicity: A review. J Forensic Leg Med., 2018; 58: 113-116.
75. Wang XB, Li GH, Zheng LJ, Ji KY, Lü H, Liu FF, Dang LZ, Mo MH, Zhang KQ. Nematicidal cardenolides from *Nerium indicum* Mill. Chem Biodivers, 2009; 6(3): 431-6.
76. Seeka C, Sutthivaiyakit S. Cytotoxic cardenolides from the leaves of *Calotropis gigantea*. Chem Pharm Bull (Tokyo), 2010; 58(5): 725-8.
77. Piacente S, Masullo M, De Nève N, Dewelle J, Hamed A, Kiss R, Mijatovic T. Cardenolides from *Pergularia tomentosa* display cytotoxic activity resulting from their potent inhibition of Na+/K+-ATPase. J Nat Prod., 2009; 72(6): 1087-91.
78. Li JZ, Qing C, Chen CX, Hao XJ, Liu HY. Cytotoxicity of cardenolides and cardenolide glycosides from *Asclepias curassavica*. Bioorg Med Chem Lett., 2009; 19(7): 1956-9.
79. Rosales PF, Bordin GS, Gower AE, Moura S. Indole alkaloids: 2012 until now, highlighting the new chemical structures and biological activities. Fitoterapia, 2020; 143: 104558.
80. Williams D, Qu Y, Simionescu R, De Luca V. The assembly of (+)-vincadifformine- and (-)-tabersonine-derived monoterpenoid indole alkaloids in *Catharanthus roseus* involves separate branch pathways. Plant J., 2019; 99(4): 626-636.
81. Liscombe DK, O'Connor SE. A virus-induced gene silencing approach to understanding alkaloid metabolism in *Catharanthus roseus*. Phytochemistry, 2011; 72(16): 1969-77.
82. Mijangos MV, Miranda LD. A unified synthesis of topologically diverse Aspidosperma alkaloids through divergent iminium-trapping. Org Biomol Chem., 2018; 16(48): 9409-9419.
83. Castillo L, Rossini C. Bignoniaceae metabolites as semiochemicals. Molecules, 2010; 15(10): 7090-105.

84. Chowański S, Adamski Z, Marciniak P, Rosiński G, Büyükgüzel E, Büyükgüzel K, Falabella P, Scrano L, Ventrella E, Lelario F, Bufo SA. A Review of Bioinsecticidal Activity of Solanaceae Alkaloids. Toxins (Basel), 2016; 8(3): 60.
85. Xia Q, Tian H, Li Y, Yu X, Zhang W, Wang Q. Biomimetic Synthesis of Iridoid Alkaloids as Novel Leads for Fungicidal and Insecticidal Agents. J Agric Food Chem., 2020; 68(45): 12577-12584.
86. Zhan G, Miao R, Zhang F, Wang X, Zhang X, Guo Z. Cytotoxic Yohimbine-Type Alkaloids from the Leaves of *Rauvolfia vomitoria*. Chem Biodivers, 2020; 17(12): e2000647.
87. Fang L, He TT, Zhu KK, Zhang M, Zhou J, Zhang H. Cytotoxic aspidosperma-type alkaloids from *Melodinus axillaris*. J Asian Nat Prod Res., 2019; 21(3): 284-290.
88. Shi BB, Chen J, Bao MF, Zeng Y, Cai XH. Alkaloids isolated from *Tabernaemontana bufalina* display xanthine oxidase inhibitory activity. Phytochemistry, 2019; 166: 112060.
89. Ma K, Wang JS, Luo J, Kong LY. Six new alkaloids from *Melodinus henryi*. Fitoterapiam, 2015; 100: 133-8.
90. He J, Zhang FL, Li ZH, Yang HX, Shao Q, Feng T, Liu JK. Monoterpenoid indole alkaloids from the bark of *Melodinus henryi*. Fitoterapia, 2019; 138: 104354.
91. Tang Y, Nugroho AE, Hirasawa Y, Tougan T, Horii T, Hadi AHA, Morita H. Leucophyllinines A and B, bisindole alkaloids from *Leuconotis eugeniifolia*. J Nat Med., 2019; 73(3): 533-540.
92. Liu JW, Huo ZQ, Zhao Q, Hao XJ, He HP, Zhang Y. Melotenuines A-E, cytotoxic monoterpenoid indole alkaloids from *Melodinus tenuicaudatus*. Fitoterapia, 2019; 138: 104347.
93. Konno K, Hirayama C, Nakamura M, Tateishi K, Tamura Y, Hattori M, Kohno K. Papain protects papaya trees from herbivorous insects: role of cysteine proteases in latex. Plant J., 2004; 37(3): 370-8.
94. Freitas CDT, Silva RO, Ramos MV, Porfírio CTMN, Farias DF, Sousa JS, Oliveira JPB, Souza PFN, Dias LP, Grangeiro TB. Identification, characterization, and antifungal activity of cysteine peptidases from *Calotropis procera* latex. Phytochemistry, 2020; 169: 112163.
95. Ramos MV, Araújo ES, Jucá TL, Monteiro-Moreira AC, Vasconcelos IM, Moreira RA, Viana CA, Beltramini LM, Pereira DA, Moreno FB. New insights into the complex mixture of latex cysteine peptidases in *Calotropis procera*. Int J Biol Macromol, 2013; 58: 211-9.

96. Freitas CD, Oliveira JS, Miranda MR, Macedo NM, Sales MP, Villas-Boas LA, Ramos MV. Enzymatic activities and protein profile of latex from *Calotropis procera*. Plant Physiol Biochem, 2007; 45(10-11): 781-9.
97. de Freitas CD, da uz WT, Silva MZ, Vasconcelos IM, Moreno FB, Moreira RA, Monteiro-Moreira AC, Alencar LM, Sousa JS, Rocha BA, Ramos MV. Proteomic analysis and purification of an unusual germin-like protein with proteolytic activity in the latex of *Thevetia peruviana*. Planta., 2016; 243(5): 1115-28.
98. Torres MJ, Natalucci C, López LMI, Trejo SA. Insights into the hydrolytic activity of *Asclepias fruticosa* L. protease. Biotechnol Lett., 2019; 41(8-9): 1043-1050.
99. Sequeiros C, Torres MJ, Trejo SA, Esteves JL, Natalucci CL, López LM. Philibertain g I, the most basic cysteine endopeptidase purified from the latex of *Philibertia gilliesii* (Apocynaceae). Protein J., 2005; 24(7-8): 445-53.
100. Shivaprasad HV, Rajesh R, Nanda BL, Dharmappa KK, Vishwanath . Thrombin like activity of *Asclepias curassavica* L. latex: action of cysteine proteases. J Ethnopharmacol, 2009; 123(1): 106-9.
101. Ramos MV, Pereira DA, Souza DP, Silva ML, Alencar LM, Sousa JS, Queiroz JF, Freitas CD. Peptidases and peptidase inhibitors in gut of caterpillars and in the latex of their host plants. Planta., 2015; 241(1): 167-78.
102. Obregón WD, Lufrano D, Liggieri CS, Trejo SA, Vairo-Cavalli SE, Avilés FX, Priolo NS. Biochemical characterization, cDNA cloning, and molecular modeling of araujiain aII, a papain-like cysteine protease from *Araujia angustifolia* latex. Planta, 2011; 234(2): 293-304.
103. Ramos MV, Souza DP, Gomes MT, Freitas CD, Carvalho CP, Júnior PA, Salas CE. A phytopathogenic cysteine peptidase from latex of wild rubber vine *yptostegia grandiflora*. Protein J., 2014; 33(2): 199-209.
104. Rascón-Valenzuela LA, Velázquez C, Garibay-Escobar A, Vilegas W, Medina-Juárez LA, Gámez-Meza N, Robles-Zepeda RE. Apoptotic activities of cardenolide glycosides from *Asclepias subulata*. J Ethnopharmacol, 2016; 193: 303-311.
105. Sequeiros C, Torres MJ, Nievas ML, Caffini NO, Natalucci CL, López LM, Trejo SA. The Proteolytic Activity of *Philibertia gilliesii* Latex. Purification of Philibertain g II. Appl Biochem Biotechnol, 2016; 179(2): 332-46.
106. Mo EP, Zhang RR, Xu J, Zhang H, Wang XX, Tan QT, Liu FL, Jiang RW, Cai SH. Calotropin from *Asclepias curasavica* induces cell cycle arrest and apoptosis in

cisplatin-resistant lung cancer cells. Biochem Biophys Res Commun, 2016; 478(2): 710-5.

107. Zhang Y, Wang H, Tao L, Huang AX. Milk-clotting mechanism of *Dregea sinensis* Hemsl. protease. J Dairy Sci., 2015; 98(12): 8445-53.
108. Ghosh R, Chakraborty S, Chakrabarti C, Dattagupta JK, Biswas S. Structural insights into the substrate specificity and activity of ervatamins, the papain-like cysteine proteases from a tropical plant, *Ervatamia coronaria*. FEBS J., 2008; 275(3): 421-34.
109. Panche A., Diwan, A., & Chandra, S. Flavonoids: An overview. *Journal of Nutritional Science,* 2016; *5:* E47.
110. Wen L, Jiang Y, Yang J, Zhao Y, Tian M, Yang B. Structure, bioactivity, and synthesis of methylated flavonoids. Ann N Y Acad Sci., 2017; 1398(1): 120-129.
111. Boué SM, Raina AK. Effects of plant flavonoids on fecundity, survival, and feeding of the Formosan subterranean termite. J Chem Ecol., 2003; 29(11): 2575-84.
112. Zhou J, Zhang L, Li Q, Jin W, Chen W, Han J, Zhang Y. Simultaneous Optimization for Ultrasound-Assisted Extraction and Antioxidant Activity of Flavonoids from *Sophora flavescens* Using Response Surface Methodology. Molecules, 2018; 24(1): 112.
113. Kong NN, Fang ST, Liu Y, Wang JH, Yang CY, Xia CH. Flavonoids from the halophyte *Apocynum venetum* and their antifouling activities against marine biofilm-derived bacteria. Nat Prod Res., 2014; 28(12): 928-31.
114. Badmus JA, Ekpo OE, Rautenbach F, Marnewick JL, Hussein AA, Hiss DC. Isolation and antioxidant activity of flavonoids from *Holarrhena floribunda* (G.don) leaves. Acta Biochim Pol., 2016; 63(2): 353-8.
115. Szostak H, Kowalewski Z. The flavonoids in the leaves of *Vinca minor* L. (Apocynaceae). Pol J Pharmacol Pharm, 1975; 27(6): 657-63.
116. Yildiz I, Sen O, Erenler R, Demirtas I, Behcet L. Bioactivity-guided isolation of flavonoids from *Cynanchum acutum* L. subsp. sibiricum (willd.) Rech. f. and investigation of their antiproliferative activity. Nat Prod Res., 2017; 31(22): 2629-2633.
117. Chien MM, Svoboda GH, Schiff PL Jr, Slatkin DJ, Knapp JE. Chemical constituents of *Echites hirsuta* (Apocynaceae). J Pharm Sci., 1979; 68(2): 247-9.
118. Tan XQ, Guo LJ, Chen HS, Wu LS, Kong FF. Study on the flavonoids constituents of *Trachelospermum jasminoides*. Zhong Yao Cai., 2010; 33(1): 58-60.

119. Fu L, Zhang S, Li N, Wang J, Zhao M, Sakai J, Hasegawa T, Mitsui T, Kataoka T, Oka S, Kiuchi M, Hirose K, Ando M. Three new triterpenes from *Nerium oleander* and biological activity of the isolated compounds. J Nat Prod, 2005; 68(2): 198-206.
120. Singh B, Sharma RA. Plant terpenes: defense responses, phylogenetic analysis, regulation and clinical applications. 3 Biotech, 2015; 5(2): 129-151.
121. Pütter KM, van Deenen N, Müller B, Fuchs L, Vorwerk K, Unland K, Bröker JN, Scherer E, Huber C, Eisenreich W, Prüfer D, Schulze Gronover C. The enzymes OSC1 and CYP716A263 produce a high variety of triterpenoids in the latex of *Taraxacum koksaghyz*. Sci Rep., 2019; 9(1): 5942.
122. Guo J, Zhou LY, He HP, Leng Y, Yang Z, Hao XJ. Inhibition of 11b-HSD1 by tetracyclic triterpenoids from *Euphorbia kansui*. Molecules, 2012; 17(10): 11826-38.
123. Jabal KA, Abdallah HM, Mohamed GA, Shehata IA, Alfaifi MY, Elbehairi SEI, Koshak AA, Ibrahim SRM. Perisomalien A, a new cytotoxic scalarane sesterterpene from the fruits of *Periploca somaliensis*. Nat Prod Res., 2020; 34(15): 2167-2172.
124. Wang Q, Li WY, Wang YD. An immunosuppressive triterpenoid saponin from the stems of *Epigynum griffithianum*. Nat Prod Res., 2020; 34(10): 1389-1393.
125. Fabio GD, Romanucci V, De Marco A, Zarrelli A. Triterpenoids from *Gymnema sylvestre* and their pharmacological activities. Molecules, 2014; 19(8): 10956-81.
126. Omoyeni OA, Meyer M, Iwuoha E, Green I, Hussein AA. An unusual 2, 3-secotaraxerene and other cytotoxic triterpenoids from *Pleiocarpa pycnantha* (Apocynaceae) leaves collected from Nigeria. Molecules, 2014; 19(3): 3389-400.
127. Hiebert-Giesbrecht MR, Escalante-Erosa F, García-Sosa K, Dzib GR, Calvo-Irabien LM, Peña-Rodríguez LM. Spatio-Temporal Variation of Terpenoids in Wild Plants of *Pentalinon andrieuxii*. Chem Biodivers, 2016; 13(11): 1521-1526.
128. Adotey JP, Adukpo GE, Opoku Boahen Y, Armah FA. A Review of the Ethnobotany and Pharmacological Importance of *Alstonia boonei* De Wild (Apocynaceae). ISRN Pharmacol, 2012; 2012: 587160.
129. Valitova JN, Sulkarnayeva AG, Minibayeva FV. Plant Sterols: Diversity, Biosynthesis, and Physiological Functions. Biochemistry (Mosc), 2016; 81(8): 819-34.
130. Beaulieu R, Grand E, Stasik I, Attoumbré J, Chesnais Q, Gobert V, Ameline A, Giordanengo P, Kovensky J. Synthesis and insecticidal activities of novel solanidine derivatives. Pest Manag Sci., 2019; 75(3): 793-800.

131. Pan L, Lezama-Davila CM, Isaac-Marquez AP, Calomeni EP, Fuchs JR, Satoskar AR, Kinghorn AD. Sterols with antileishmanial activity isolated from the roots of *Pentalinon andrieuxii*. Phytochemistry, 2012; 82: 128-35.
132. Wang CM, Yeh KL, Tsai SJ, Jhan YL, Chou CH. Anti-Proliferative Activity of Triterpenoids and Sterols Isolated from *Alstonia scholaris* against Non-Small-Cell Lung Carcinoma Cells. Molecules, 2017; 22(12): 2119.
133. Vats S, Kamal R. In vivo and in vitro evaluation of sterols from *Gymnema sylvestrte* R. Br. Pak J Biol Sci., 2013; 16(23): 1771-5.
134. Liu JC, Yu LL, Tang MX, Lu XJ, Zhao D, Wang HF, Chen G, Su GY, Pei YH. Two new steroidal saponins from the roots of *Cynanchum limprichtii*. J Asian Nat Prod Res., 2018; 20(9): 875-882.
135. Zhang NL, Liu X, Shen XC, Cai JZ, Hu YJ, Qiu SX. Chemical Constituents from *Periploca forrestii*. Zhong Yao Cai., 2016; 39(2): 329-30.
136. Babaamer ZY, Sakhri L, Al-Jaber HI, Al-Qudah MA, Abu Zarga MH. Two new taraxasterol-type triterpenes from *Pergularia tomentosa* growing wild in Algeria. J Asian Nat Prod Res., 2012; 14(12): 1137-43.
137. Kaunda JS, Zhang YJ. The Genus *Carissa*: An Ethnopharmacological, Phytochemical and Pharmacological Review. Nat Prod Bioprospect, 2017; 7(2): 181-199.
138. Patil RP, Pai SR, Pawar NV, Shimpale VB, Patil RM, Nimbalkar MS. Chemical characterization, mineral analysis, and antioxidant potential of two underutilized berries (*Carissa carandus* and *Eleagnus conferta*) from the Western Ghats of India. it Rev Food Sci Nutr., 2012; 52(4): 312-20.
139. Sabira Begum, Saqib A. Syed, Bina S. Siddiqui, Samina A. Sattar, M. Iqbal Choudhary. Carandinol: First isohopane triterpene from the leaves of *Carissa carandas* L. and its cytotoxicity against cancer cell lines. Phytochemistry Letters, 2013; 6(1): 91-95.
140. Choi YH, Tapias EC, Kim HK, Lefeber AW, Erkelens C, Verhoeven JT, Brzin J, Zel J, Verpoorte R. Metabolic discrimination of *Catharanthus roseus* leaves infected by phytoplasma using 1H-NMR spectroscopy and multivariate data analysis. Plant Physiol, 2004; 135(4): 2398-410.
141. Nieto G, Ros G, Castillo J. Antioxidant and Antimicrobial Properties of Rosemary (*Rosmarinus officinalis,* L.): A Review. Medicines (Basel), 2018; 5(3): 98.
142. Lin M, Han P, Li Y, Wang W, Lai D, Zhou L. Quinoa Secondary Metabolites and Their Biological Activities or Functions. Molecules, 2019; 24(13): 2512.

143. Shi C, Xu MJ, Bayer M, Deng ZW, Kubbutat MH, Wätjen W, Proksch P, Lin WH. Phenolic compounds and their anti-oxidative properties and protein kinase inhibition from the Chinese mangrove plant *Laguncularia racemosa*. Phytochemistry, 2010; 71(4): 435-42.
144. Bastos KX, Dias CN, Nascimento YM, da Silva MS, Langassner SM, Wessjohann LA, Tavares JF. Identification of Phenolic Compounds from *Hancornia speciosa* (Apocynaceae) Leaves by UHPLC Orbitrap-HRMS. Molecules, 2017; 22(1): 143.
145. Sánchez-Gutiérrez JA, Moreno-Lorenzana D, Álvarez-Bernal D, Rodríguez-Campos J, Medina-Medrano JR. Phenolic Profile, Antioxidant and Anti-Proliferative Activities of Methanolic Extracts from *Asclepias linaria* Cav. Leaves. Molecules, 2019; 25(1): 54.
146. Souilem F, Dias MI, Barros L, Calhelha RC, Alves MJ, Harzallah-Skhiri F, Ferreira ICFR. Phenolic Profile and Bioactive Properties of *Carissa macrocarpa* (Eckl.). An *In Vitro* Comparative Study between Leaves, Stems, and Flowers. Molecules, 2019; 24(9): 1696.
147. Uchikura T, Tanaka H, Sugiwaki H, Yoshimura M, Sato-Masumoto N, Tsujimoto T, Uchiyama N, Hakamatsuka T, Amakura Y. Preliminary Quality Evaluation and Characterization of Phenolic Constituents in *Cynanchi Wilfordii* Radix. Molecules, 2018; 23(3): 656.
148. Pal R, Kulshreshtha DK, Rastogi RP. A new lignan from *Carissa carandas*. Phytochemistry, 1975; 2303(10): A2.
149. Şöhretoğlu D, Masullo M, Piacente S, Kirmizibekmez H. Iridoids, monoterpenoid glucoindole alkaloids and flavonoids from *Vinca major*. Biochemical Systematics and Ecology, 2013; 49: 69-72.
150. Parhira S, Yang ZF, Zhu GY, Chen QL, Zhou BX, Wang YT, Liu L, Bai LP, Jiang ZH. In vitro anti-influenza virus activities of a new lignan glycoside from the latex of *Calotropis gigantea*. PLoS One, 2014; 9(8): e104544.
151. Ghosh A, Chowdhury N, Chandra G. Plant extracts as potential mosquito larvicides. Indian J Med Res., 2012; 135(5): 581-98.
152. Govindarajan M, Sivakumar R, Rajeswary M, Yogalakshmi K. Chemical composition and larvicidal activity of essential oil from *Ocimum basilicum* (L.) against *Culex tritaeniorhynchus*, *Aedes albopictus* and *Anopheles subpictus* (Diptera: Culicidae). Exp Parasitol, 2013; 134(1): 7-11.

153. Tan WH, Tao L, Hoang KM, Hunter MD, de Roode JC. The Effects of Milkweed Induced Defense on Parasite Resistance in Monarch Butterflies, *Danaus plexippus*. J Chem Ecol, 2018; 44(11): 1040-1044.
154. Hoekou YP, Tchacondo T, Karou SD, Koudouvo K, Atakpama W, Pissang P, Gbogbo AK, Woegan AY, Batawila K, Akpagana K, Gbeassor M. Ethnobotanical Study of Latex Plants in the Maritime Region of Togo. Pharmacognosy Res., 2016; 8(2): 128-34.
155. R. K. Upadhyay. Plant latex: its toxicity and defense against herbivorous insects: A review. International Journal of Current Research, 2012; 4(01): 5-10.
156. Guo J, Zhou LY, He HP, Leng Y, Yang Z, Hao XJ. Inhibition of 11b-HSD1 by tetracyclic triterpenoids from *Euphorbia kansui*. Molecules, 2012; 17(10): 11826-38.
157. Chandrasekaran R, Seetharaman P, Krishnan M, Gnanasekar S, Sivaperumal S. *Carica papaya* (Papaya) latex: a new paradigm to combat against dengue and filariasis vectors *Aedes aegypti* and *Culex quinquefasciatus* (Diptera: Culicidae). 3 Biotech, 2018; 8(2): 83.
158. de Araújo KM, de Lima A, Silva Jdo N, Rodrigues LL, Amorim AG, Quelemes PV, Dos Santos RC, Rocha JA, de Andrades ÉO, Leite JR, Mancini-Filho J, da Trindade RA. Identification of Phenolic Compounds and Evaluation of Antioxidant and Antimicrobial Properties of *Euphorbia Tirucalli* L. Antioxidants (Basel), 2014; 3(1): 159-75.
159. Ayatollahi AM, Ghanadian M, Afsharypuor S, Siddiq S, Pour-Hosseini SM. Biological screening of *Euphorbia aellenii*. Iran J Pharm Res., 2010; 9(4): 429-36.
160. Nikkon F, Habib MR, Saud ZA, Karim MR. *Tagetes erecta* Linn. and its mosquitocidal potency against *Culex quinquefasciatus*. Asian Pac J Trop Biomed, 2011; 1(3): 186-8.
161. Konno K, Ono H, Nakamura M, Tateishi K, Hirayama C, Tamura Y, Hattori M, Koyama A, Kohno K. Mulberry latex rich in antidiabetic sugar-mimic alkaloids forces dieting on caterpillars. Proc Natl Acad Sci U S A., 2006; 103(5): 1337-41.
162. Dussourd DE. *Theroa zethus* Caterpillars Use Acid Secretion of Anti-Predator Gland to Deactivate Plant Defense. PLoS One, 2015; 10(10): e0141924.
163. Ernst M, Nothias LF, van der Hooft JJJ, Silva RR, Saslis-Lagoudakis CH, Grace OM, Martinez-Swatson K, Hassemer G, Funez LA, Simonsen HT, Medema MH, Staerk D, Nilsson N, Lovato P, Dorrestein PC, Rønsted N. Assessing Specialized Metabolite Diversity in the Cosmopolitan Plant Genus *Euphorbia* L. Front Plant Sci., 2019; 10: 846.

164. Gaupels F, Sarioglu H, Beckmann M, Hause B, Spannagl M, Draper J, Lindermayr C, Durner J. Deciphering systemic wound responses of the pumpkin extrafascicular phloem by metabolomics and stable isotope-coded protein labeling. Plant Physiol, 2012; 160(4): 2285-99.
165. Pütter KM, van Deenen N, Müller B, Fuchs L, Vorwerk K, Unland K, Bröker JN, Scherer E, Huber C, Eisenreich W, Prüfer D, Schulze Gronover C. The enzymes OSC1 and CYP716A263 produce a high variety of triterpenoids in the latex of *Taraxacum koksaghyz*. Sci Rep., 2019; 9(1): 5942.
166. Murthy HN, Joseph KS, Payamalle S, Dalawai D, Ganapumane V. Chemical composition, larvicidal and antioxidant activities of latex from *Garcinia morella* (Gaertn.) Desr. J Parasit Dis., 2017; 41(3): 666-670.
167. Megeressa M, Bisrat D, Mazumder A, Asres K. Structural elucidation of some antimicrobial constituents from the leaf latex of *Aloe trigonantha* L.C. Leach. BMC Complement Altern Med., 2015; 15: 270.
168. Kitajima S, Kamei K, Taketani S, Yamaguchi M, Kawai F, Komatsu A, Inukai Y. Two chitinase-like proteins abundantly accumulated in latex of mulberry show insecticidal activity. BMC Biochem, 2010; 11: 6.
169. Parachnowitsch AL, Caruso CM, Campbell SA, Kessler A. *Lobelia siphilitica* plants that escape herbivory in time also have reduced latex production. PLoS One, 2012; 7(5): e37745.
170. Fürstenberg-Hägg J, Zagrobelny M, Bak S. Plant defense against insect herbivores. Int J Mol Sci., 2013; 14(5): 10242-97.
171. Gastaldo C, Lipko A, Motsch E, Adam P, Schaeffer P, Rohmer M. Biosynthesis of Isoprene Units in *Euphorbia lathyris* Laticifers vs. Other Tissues: MVA and MEP Pathways, Compartmentation and Putative Endophytic Fungi Contribution. Molecules, 2019; 24(23): 4322.
172. Fruttero LL, Moyetta NR, Uberti AF, Grahl MV, Lopes FC, Broll V, Feder D, Carlini . Humoral and cellular immune responses induced by the urease-derived peptide Jaburetox in the model organism *Rhodnius prolixus*. Parasit Vectors, 2016; 9(1): 412.
173. Batool M, Hussain D, Akrem A, Najam-Ul-Haq M, Saeed S, Zaka SM, Nawaz MS, Buck F, Saeed Q. Graphene quantum dots as cysteine protease nanocarriers against stored grain insect pests. Sci Rep., 2020; 10(1): 3444.
174. Harrison RL, Bonning BC. Proteases as insecticidal agents. Toxins (Basel), 2010; 2(5): 935-53.

175. Asmerom D, Hailu GS, Yimer EM, Bitew H, Kahsay G. Antimicrobial Evaluation of Latex and TLC Fractions from the Leaves of *Aloe adigratana* Reynolds. Evid Based Complement Alternat Med., 2020; 2020: 8312471.
176. Rasmann S, Turlings TC. Simultaneous feeding by aboveground and belowground herbivores attenuates plant-mediated attraction of their respective natural enemies. Ecol Lett., 2007; 10(10): 926-36.
177. Shi J, Li Z, Izumi M, Baba N, Nakajima S. Termiticidal activity of diterpenes from the roots of *Euphorbia kansui*. Z Naturforsch C J Biosci, 2008; 63(1-2): 51-8.
178. Morimoto M, Fukumoto H, Hiratani M, Chavasiri W, Komai K. Insect antifeedants, pterocarpans and pterocarpol, in heartwood of *Pterocarpus macrocarpus* Kruz. Biosci Biotechnol Biochem, 2006; 70(8): 1864-8.
179. Smith PA, Thompson MJ, Edwards JW. Estimating occupational exposure to the pyrethroid termiticide bifenthrin by measuring metabolites in urine. J Chromatogr B Analyt Technol Biomed Life Sci., 2002; 778(1-2): 113-20.
180. Charalampous AC, Liapis KS, Bempelou ED. Fipronil in eggs. Is LC-MS/MS the only option? A comparison study of LC-MS/MS and GC-ECD for the analysis of fipronil. J Chromatogr B Analyt Technol Biomed Life Sci., 2019; 1129: 121785.
181. dos Santos A, Zanetti R, dos Santos JC, Biagiotti G, Evangelista AL, Serrão JE, Zanuncio JC. Persistence of fipronil residues in *Eucalyptus* seedlings and its concentration in the insecticide solution after treatment in the nursery. Environ Monit Assess, 2016; 188(5): 314.
182. Ripa R, Luppichini P, Su NY, Rust MK. Field evaluation of potential control strategies against the invasive eastern subterranean termite (Isoptera: Rhinotermitidae) in Chile. J Econ Entomol, 2007; 100(4): 1391-9.
183. Tingle CC, Rother JA, Dewhurst CF, Lauer S, King WJ. Fipronil: environmental fate, ecotoxicology, and human health concerns. Rev Environ Contam Toxicol, 2003; 176: 1-66.
184. Asakawa F, Jitsunari F, Nakajima T, Shimada J, Ogata M. Determination of 3,5,6-trichloro-2-pyridinol levels in the urine of termite control workers using chlorpyrifos. Acta Med Okayama, 1989; 43(5): 299-306.
185. Racke KD. Environmental fate of chlorpyrifos. Rev Environ Contam Toxicol, 1993; 131: 1-150.
186. Guan YQ, Chen JM, Li ZB, Feng QL, Liu JM. Immobilisation of bifenthrin for termite control. Pest Manag Sci., 2011; 67(2): 244-51.

187. Manzoor F, Pervez M. HPLC Analysis to Determine the Half-life and Bioavailability of the Termiticides Bifenthrin and Fipronil in Soil. J Econ Entomol, 2017; 110(6): 2527-2533.
188. Barwary Z, Gorzlancyk A, Hu XP. Effects of concentration, distance, and application methods of Altriset (Chlorantraniliprole) on eastern subterranean termite (Isoptera: Rhinotermitidae). Insect Sci., 2015; 22(3): 451-60.
189. Gautam BK, Henderson G. Effect of soil type and exposure duration on mortality and transfer of chlorantraniliprole and fipronil on Formosan subterranean termites (Isoptera: Rhinotermitidae). J Econ Entomol, 2011; 104(6): 2025-30.
190. Saran RK, Ziegler M, Kudlie S, Harrison D, Leva DM, Scherer C, Coffelt MA. Behavioral Effects and Tunneling Responses of Eastern Subterranean Termites (Isoptera: Rhinotermitidae) Exposed to Chlorantraniliprole-Treated Soils. J Econ Entomol, 2014; 107(5): 1878-89.
191. Buczkowski G, Scherer CW, Bennetti GW. Toxicity and horizontal transfer of chlorantraniliprole in the eastern subterranean termite. J Econ Entomol, 2012; 105(5): 1736-45.
192. Veillon L, Bourgeois J, Leblanc A, Henderson G, Marx BD, Muniruzzaman S, Laine RA. Myo-inositol and Phytate Are Toxic to Formosan Subterranean Termites (Isoptera: Rhinotermitidae). J Econ Entomol, 2014; 107(5): 1800-12.
193. Peters BC, Fitzgerald CJ. Field evaluation of the bait toxicant chlorfluazuron in eliminating *Coptotermes acinaciformis* (Froggatt) (Isoptera: Rhinotermitidae). J Econ Entomol, 2003; 96(6): 1828-31.
194. Katsuda Y, Minamite Y, Vongkaluang C. Development of Silafluofen-Based Termiticides in Japan and Thailand. Insects, 2011; 2(4): 532-9.
195. Peterson CJ, Davis RW. Mobility, longevity and activity of chlorfenapyr in soils treated at a termiticidal rate. Pest Manag Sci., 2013; 69(1): 88-92.
196. Ejomah AJ, Uyi OO, Ekaye SO. Exposure of the African mound building termite, *Macrotermes bellicosus* workers to commercially formulated 2,4-D and atrazine caused high mortality and impaired locomotor response. PLoS One, 2020; 15(3): e0230664.
197. Iqbal N, Evans TA. Evaluation of fipronil and imidacloprid as bait active ingredients against fungus-growing termites (Blattodea: Termitidae: Macrotermitinae). Bull Entomol Res., 2018; 108(1): 14-22.
198. Morita M. Chlorinated benzenes in the environment. Ecotoxicol Environ Saf, 1977; 1(1): 1-6.

199. Brandford MM, Kingsley O, Snr AA, Yaw D, Lante LJN, Ama ES. Effect of azadirachtin pre-treatment on major pests, diseases and yield of seed yam. J Entomol Nematol, 2019; 11(2): 13-20.
200. Phillips PJ, Nowell LH, Gilliom RJ, Nakagaki N, Murray KR, VanAlstyne C. Composition, distribution, and potential toxicity of organochlorine mixtures in bed sediments of streams. Sci Total Environ, 2010; 408(3): 594-606.
201. Bhatta D, Henderson G. Horizontal Transfer of Spinosad in *Coptotermes formosanus* (Isoptera: Rhinotermitidae). J Econ Entomol, 2016; 109(4): 1813-8.
202. Abram PK, Moffat CE. Rethinking biological control programs as planned invasions. Curr Opin Insect Sci., 2018; 27: 9-15.
203. Grønvold J, Henriksen SA, Larsen M, Nansen P, Wolstrup J. Biological control. Aspects of biological control--with special reference to arthropods, protozoans and helminths of domesticated animals. Vet Parasitol, 1996; 64(1-2): 47-64.
204. Mills NJ, Heimpel GE. Could increased understanding of foraging behavior help to predict the success of biological control? Curr Opin Insect Sci., 2018; 27: 26-31.
205. Petráková L, Líznarová E, Pekár S, Haddad , Sentenská L, Symondson WO. Discovery of a monophagous true predator, a specialist termite-eating spider (Araneae: Ammoxenidae). Sci Rep., 2015; 5: 14013.
206. Fayle TM, Scholtz O, Dumbrell AJ, Russell S, Segar ST, Eggleton P. Detection of mitochondrial COII DNA sequences in ant guts as a method for assessing termite predation by ants. PLoS One, 2015; 10(4): e0122533.
207. Sahayaraj K, Subash N, Allingham RW, Kumar V, Avery PB, Mehra LK, McKenzie CL, Osborne LS. Lethal and Sublethal Effects of Three Microbial Biocontrol Agents on *Spodoptera litura* and Its Natural Predator *Rhynocoris kumarii*. Insects, 2018; 9(3): 101.
208. Burges, H. Control of insects by bacteria. *Parasitology*, 1982; *84*(4): 79-117.
209. Lacey LA, Grzywacz D, Shapiro-Ilan DI, Frutos R, Brownbridge M, Goettel MS. Insect pathogens as biological control agents: Back to the future. J Invertebr Pathol, 2015; 132: 1-41.
210. Sapountzis P, Gruntjes T, Otani S, Estevez J, da Costa RR, Plunkett G 3rd, Perna NT, Poulsen M. The Enterobacterium *Trabulsiella odontotermitis* Presents Novel Adaptations Related to Its Association with Fungus-Growing Termites. Appl Environ Microbiol, 2015; 81(19): 6577-88.

211. Tikhe CV, Martin TM, Howells A, Delatte J, Husseneder C. Assessment of genetically engineered *Trabulsiella odontotermitis* as a 'Trojan Horse' for paratransgenesis in termites. BMC Microbiol, 2016; 16(1): 202.
212. Keppanan R, Sivaperumal S, Ramos Aguila LC, Hussain M, Bamisile , Dash CK, Wang L. Isolation and characterization of *Metarhizium anisopliae* TK29 and its mycoinsecticide effects against subterranean termite *Coptotermes formosanus*. Microb Pathog, 2018; 123: 52-59.
213. Wright MS, Raina AK, Lax AR. A strain of the fungus *Metarhizium anisopliae* for controlling subterranean termites. J Econ Entomol, 2005; 98(5): 1451-8.
214. Ambele CF, Ekesi S, Bisseleua HDB, Babalola OO, Khamis FM, Djuideu CTL, Akutse KS. Entomopathogenic Fungi as Endophytes for Biological Control of Subterranean Termite Pests Attacking Cocoa Seedlings. J Fungi (Basel), 2020; 6(3): 126.
215. Wright MS, Lax AR. Combined effect of microbial and chemical control agents on subterranean termites. J Microbiol, 2013; 51(5): 578-83.
216. Tatun N, Wangsantitham O, Tungjitwitayakul J, Sakurai S. Trehalase activity in fungus-growing termite, *Odontotermes feae* (Isoptera: Termitideae) and inhibitory effect of validamycin. J Econ Entomol, 2014; 107(3): 1224-32.
217. Teetor-Barsch GH, Roberts DW. Entomogenous *Fusarium* species. Mycopathologia. 1983; 84(1): 3-16.
218. Wright MS, Cornelius ML. Mortality and repellent effects of microbial pathogens on *Coptotermes formosanus* (Isoptera: Rhinotermitidae). BMC Microbiol, 2012; 12: 291.
219. Zhao R, Han R, Qiu X, Yan X, Cao L, Liu X. Cloning and heterologous expression of insecticidal-protein-encoding genes from *Photorhabdus luminescens* TT01 in Enterobacter cloacae for termite control. Appl Environ Microbiol, 2008; 74(23): 7219-26.
220. Noknoy R, Sunantaraporn S, Phumee A, Siriyasatien P, Sanguansub S. Parasitism of Soldiers of the Termite, *Macrotermes gilvus* (Hagen), by the Scuttle Fly, *Megaselia scalaris* (Loew) (Diptera: Phoridae). Insects, 2020; 11(5): 318.
221. Al-Zaidawi JB, Karimi J, Mahdikhani Moghadam E. Entomopathogenic Nematodes as Potential Biological Control Agents of Subterranean Termite, *Microcerotermes diversus* (Blattodea: Termitidae) in Iraq. Environ Entomol, 2020; 49(2): 412-421.
222. Yu H, Gouge DH, Baker P. Parasitism of subterranean termites (Isoptera: Rhinotermitidae: Termitidae) by entomopathogenic nematodes (Rhabditida: Steinernematidae; Heterorhabditidae). J Econ Entomol, 2006; 99(4): 1112-9.

223. Massey CL. Two new genera of nematodes parasitic in the eastern subterranean termite, *Reticulitermes flavipes*. J Invertebr Pathol, 1971; 17(2): 238-42.
224. Yu H, Gouge DH, Shapiro-Ilan DI. A novel strain of *Steinernema riobrave* (Rhabditida: Steinernematidae) possesses superior virulence to subterranean termites (Isoptera: Rhinotermitidae). J Nematol, 2010; 42(2): 91-5.
225. Hu J, Neoh KB, Appel AG, Lee CY. Subterranean termite open-air foraging and tolerance to desiccation: Comparative water relation of two sympatric *Macrotermes* spp. (Blattodea: Termitidae). Comp Biochem Physiol A Mol Integr Physiol, 2012; 161(2): 201-7.
226. Quarcoo FY, Hu XP, Appel AG. Effects of non-repellent termiticides on the tunneling and walking ability of the eastern subterranean termite (Isoptera: Rhinotermitidae). Pest Manag Sci., 2012; 68(10): 1352-9.
227. Ferreira DV, Sacramento JJM, Rocha MLC, uz JS, Santana DL, istaldo PF, Araújo APA. Does Distance among Colonies and Resource Availability Explain the Intercolonial Aggressiveness in *Nasutitermes aff. coxipoensis*? Neotrop Entomol, 2018; 47(6): 808-814.
228. Henderson G, Gautam BK, Wang C. Impact of Ground-Applied Termiticides on the Above-Ground Foraging Behavior of the Formosan Subterranean Termite. Insects, 2016; 7(3): 43.
229. Ulyshen MD, Shelton TG. Evidence of cue synergism in termite corpse response behavior. *Naturwissenschaften*, 2012; 99(2): 89-93.
230. Thorne BL, Breisch NL. Effects of sublethal exposure to imidacloprid on subsequent behavior of subterranean termite *Reticulitermes virginicus* (Isoptera: Rhinotermitidae). J Econ Entomol, 2001; 94(2): 492-8.
231. Grimball B, Veillon L, Calhoun T, Fronczek FR, Arceneaux E, Laine RA. Cyclohexylamine inexplicably induces antennae loss in Formosan subterranean termites (*Coptotermes formosanus* Shiraki): cyclohexylamine hydrogen phosphate salts are novel termiticides. Pest Manag Sci., 2017; 73(10): 2039-2047.
232. Kocher SD, Grozinger CM. Cooperation, conflict, and the evolution of queen pheromones. J Chem Ecol, 2011; 37(11): 1263-75.
233. GaoY, Huang Q, Xu H. Silencing Orco Impaired the Ability to Perceive Trail Pheromones and Affected Locomotion Behavior in Two Termite Species. J Econ Entomol, 2020; 113(6): 2941-2949.

234. James F.A. Traniello. Mario L. Muscedere, Tara A. Willey. Age and task efficiency in the ant *Pheidole dentata*: young minor workers are not specialist nurses. Animal Behaviour, 2009; 77(4): 911-918.
235. Schwinghammer MA, Zhou X, Kambhampati S, Bennett GW, Scharf ME. A novel gene from the takeout family involved in termite trail-following behavior. Gene, 2011; 474(1-2): 12-21.
236. Wen P, Mo J, Lu C, Tan K, Šobotník J, Sillam-Dussès D. Sex-pairing pheromone of *Ancistrotermes dimorphus* (Isoptera: Macrotermitinae). J Insect Physiol, 2015; 83: 8-14.
237. Wen P, Ji BZ, Liu SW, Liu C, Sillam-Dussès D. Sex-pairing pheromone in the Asian termite pest species *Odontotermes formosanus*. J Chem Ecol., 2012; 38(5): 566-75.
238. Zhou X, Wheeler MM, Oi FM, Scharf ME. RNA interference in the termite *Reticulitermes flavipes* through ingestion of double-stranded RNA. Insect Biochem Mol Biol., 2008; 38(8): 805-15.
239. Masuoka Y, Yaguchi H, Suzuki R, Maekawa K. Knockdown of the juvenile hormone receptor gene inhibits soldier-specific morphogenesis in the damp-wood termite *Zootermopsis nevadensis* (Isoptera: Archotermopsidae). Insect Biochem Mol Biol., 2015; 64: 25-31.
240. Wu W, Gu D, Yan S, Li Z. RNA interference of endoglucanases in the formosan subterranean termite *Coptotermes formosanus* shiraki (Blattodea: Rhinotermitidae) by dsRNA injection or ingestion. J Insect Physiol, 2019; 112: 15-22.
241. Zhao R, Han R, Qiu X, Yan X, Cao L, Liu X. Cloning and heterologous expression of insecticidal-protein-encoding genes from *Photorhabdus luminescens* TT01 in *Enterobacter cloacae* for termite control. Appl Environ Microbiol, 2008; 74(23): 7219-26.
242. Husseneder C, Sethi A, Foil L, Delatte J. Testing protozoacidal activity of ligand-lytic peptides against termite gut protozoa in vitro (protozoa culture) and in vivo (microinjection into termite hindgut). J Vis Exp., 2010; 46: 2190.
243. Javadpour MM, Juban MM, Lo WC, Bishop SM, Alberty JB, Cowell SM, Becker CL, McLaughlin ML. De novo antimicrobial peptides with low mammalian cell toxicity. J Med Chem., 1996; 39(16): 3107-13.
244. Husseneder C, Donaldson JR, Foil LD. Genetically Engineered Yeast Expressing a Lytic Peptide from Bee Venom (Melittin) Kills Symbiotic Protozoa in the Gut of Formosan Subterranean Termites. PLoS One, 2016; 11(3): e0151675.

245. Hussain A, Tian MY, Wen SY. Exploring the Caste-Specific Multi-Layer Defense Mechanism of Formosan Subterranean Termites, *Coptotermes formosanus* Shiraki. Int J Mol Sci., 2017; 18(12): 2694.
246. Cristaldo PF, Jandák V, Kutalová K, Rodrigues VB, Brothánek M, Jiříček O, DeSouza O, Šobotník J. The nature of alarm communication in *Constrictotermes cyphergaster* (Blattodea: Termitoidea: Termitidae): the integration of chemical and vibroacoustic signals. Biol Open, 2015; 4(12): 1649-59.
247. Cornette R, Matsumoto T, Miura T. Histological analysis of fat body development and molting events during soldier differentiation in the damp-wood termite, *Hodotermopsis sjostedti* (Isoptera, Termopsidae). Zoolog Sci., 2007; 24(11): 1066-74.
248. Wimmer Z, Kuldová J, Hrdý I, Bennettová B. Can juvenogens, biochemically targeted hormonogen compounds, assist in environmentally safe insect pest management? Insect Biochem Mol Biol., 2006; 36(6): 442-53.
249. Tykva R, Cerný B, Wimmer Z, Hanus R. Distribution of a juvenogen and its metabolites in a laboratory system during juvenogen-induced caste differentiation in a termite, *Reticulitermes santonensis* (Isoptera: Rhinotermitidae). Pest Manag Sci., 2008; 64(6): 654-9.
250. Hrdý I, Kuldová J, Wimmer Z. Juvenogens as potential agents in termite control: laboratory screening. Pest Manag Sci., 2004; 60(10): 1035-42.
251. Tarver MR, Florane CB, Zhang D, Grimm C, Lax AR. Methoprene and temperature effects on caste differentiation and protein composition in the Formosan Subterranean termite, *Coptotermes formosanus*. J Insect Sci., 2012; 12: 18.
252. Evans TA, Iqbal N. Termite (order Blattodea, infraorder Isoptera) baiting 20 years after commercial release. Pest Manag Sci., 2015; 71(7): 897-906.
253. Hamm RL, DeMark JJ, Chin-Heady E, Tolley MP. Consumption of a durable termite bait matrix by subterranean termites (Isoptera: Rhinotermitidae) and resulting insecticidal activity. Pest Manag Sci., 2013; 69(4): 507-11.
254. Kakkar G, Su NY. Molting drives mortality in foraging populations of Formosan subterranean termites (Isoptera: Rhinotermitidae) baited with a chitin synthesis inhibitor, noviflumuron. Pest Manag Sci., 2018; 74(1): 219-224.
255. Lee CC, Neoh KB, Lee CY. Colony size affects the efficacy of bait containing chlorfluazuron against the fungus-growing termite *Macrotermes gilvus* (Blattodea: Termitidae). J Econ Entomol, 2014; 107(6): 2154-62.

256. Iqbal N, Evans TA. Evaluation of fipronil and imidacloprid as bait active ingredients against fungus-growing termites (Blattodea: Termitidae: Macrotermitinae). Bull Entomol Res., 2018; 108(1): 14-22.
257. Rojas MG, Morales-Ramos JA. Bait matrix for delivery of chitin synthesis inhibitors to the formosan subterranean termite (Isoptera: Rhinotermitidae). J Econ Entomol, 2001; 94(2): 506-10.
258. Hiusen TJ, Kamble-Shripat T. Delayed toxicity of two chitinolytic enzyme inhibitors (psammaplin a and pentoxifylline) against eastern subterranean termites (Isoptera: Rhinotermitidae). J Econ Entomol, 2013; 106(4): 1788-93.
259. Osbrink WL, Cornelius ML, Lax AR. Areawide field study on effect of three chitin synthesis inhibitor baits on populations of *Coptotermes formosanus* and *Reticulitermes flavipes* (Isoptera: Rhinotermitidae). J Econ Entomol, 2011; 104(3): 1009-17.
260. Bernard S, Osbrink W, Su NY. Response of the formosan subterranean termite to neighboring con-specific populations after baiting with noviflumuron. J Econ Entomol, 2017; 110(2): 575-583.
261.