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Termite, a Hidden Enemy of Crops: A Review

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Abstract: Termites are social insects of the order Isoptera. It is belonging to the insect infra order Isoptera and are characterized by their colonial behavior. In Africa at large and Ethiopia in particular, the most important termite genera are *Macrotermes, Odnotermes, Pseudocanthotermes, Ancistrotermes and Microterme* termites. They are found on all continents except Antarctica. The term "hidden enemy" is used in this review because most of the loss caused by termite is during growing time feeding on the roots of crops under the soils. Habitats are the heaviest in the tropic regions, subtropics, and warmer climate regions. It's predominantly distributed in tropical environment, with the highest species richness in equatorial rainforest. Termites mostly feed on dead plant material and cellulose, generally in the form of wood, leaf litter, soil, or animal dung. Moreover the harmful effect of termite outweighs positive effects. Termite cause wide spread damage to a great variety of crops in tropical Africa. The yield loss from damage of termite in Ethiopia can ranges from 8.6% to 81.4%. Different management techniques are available for controlling termite. However the efficiency of controlling mechanism depends on distribution, biology (reproduction and lifecycle) and ecology of termite species occupying an area. Moreover ITM (Integrated termite management) is environmentally safe and economically affordable mechanism of termite management. Hence the area of this review focuses on distribution of subterranean termite, biology and management techniques. Therefore, distribution, biology and management techniques reviewed in current paper really helpful as source of information for researcher, developmental agents and crop producers about termite, which is neglected crop enemy and currently cause huge loss in agricultural products.

Keywords: Biology, Castes, Distribution, Ecology, Microtermes, Mound, Termites

1. Introduction

Termites are social insects of the order Isoptera with about 3000 species [29] in 281 genera [14], fifteen subfamilies and seven families. It is dominant arthropod detritivore important in decomposition process. Termites are eusocial insects belonging to the insect infra order Isoptera and are characterized by their colonial behavior. Their influence on decomposition processes at any site is likely to be governed to a large extent by the species composition and the local termite assemblage [17].

Termite diversity, composition and their associated functions vary within and between ecosystems and these may shift under changing land-uses [34]. Like ants and some bees and wasps from the separate order Hymenoptera, termites divide labor among castes consisting of sterile male and female workers and soldiers. All colonies have fertile males called kings and one or more fertile females called queens [14]. Termites mostly feed on dead plant material and cellulose, generally in the form of wood, leaf litter, soil, or animal dung. Winged individuals have two pairs of wings, which are similar in size and shape. It lives in colonies consisting of a few thousands to several million individuals [1].

Among the taxonomic group of termite, *microtermes* species include *Microtermes obesi*, *microtermes adschaggae* and Microtermes mycophagus is a common species of termite of the genus *Microtermes.* These termites are cream colored with dark head. They damage cereal crops just after sowing and close to the maturity. Heavily infected plants may wilt and can pulled out easily, especially shallow rooted cereals like wheat and teff [16]. Termites have both

beneficial and harmful effects in the ecosystem. It is major detritivore particularly in the subtropical and tropical regions, and their recycling of wood and plant matter is of considerable ecological importance. Moreover termite is most important and most efficient lignocelluloses decomposer. They contribute great role in the organic matter decomposition, that lead to addition of soil fertility and food source for other organism [3].

The harmful effect includes damage to human wants like crop, trees, building and wooden materials. Therefore the objectives of this review where to provide the information on termite biology, distributions and management practice specifically at Ethiopian condition. The economic importance reviewed in this paper could also help the government or policy makers to give priorities to take control measure against termite since it is hidden enemy of crops and resources that cause huge economic loss both directly and indirectly than any other pest. The research gap mentioned in the review also helps the researcher and other bodies to have plans on it to fulfill the gap of information.

2. Distributions

Termites are found on all continents except Antarctica and the termite species spans the entire world [9]. Habitats are the heaviest in the tropic regions, subtropics, and warmer climate regions. Termites thrive in the warm moist lowlands and along coasts [10]. It's predominantly distributed in tropical environment, with the highest species richness in equatorial rainforest, and generally declining with increasing latitude. The species diversity and distribution of termite vary from continent to continent and also vary from one country to others within the same country [12].

Worldwide, the distribution and diversity of termite species is not the same. Ten species known in Europe and 50 in North America, but is high in South America, where over 400 species are known. In Asia, there are 435 species of termites, which are mainly distributed in China. Within China, termite species are restricted to mild tropical and subtropical habitats south of the Yangtze River. Of the 3,000 termite species classified, 1,000 are found in Africa with variable ecological distribution of their mounds [10, 28].

Termite species composition with its ecological distribution in Ethiopia at the central rift valley indicated Seven genera, viz *Macrotermes, Odontoterms, Microtermes, Amitermes, Microcerotermes, Angulitermes, and Trinervitermes* from which the first 5 genera were highly distributed across the sampled area *while Angulitermes and Trinervitermes* were very rare and recorded only from protected lands [6]. Termites were sampled from different land-use types i.e protected lands, rangelands, and farmlands using the standardized belt transect and maize stalk baiting. The three land-use types were not equally managed by man, the protected lands being the least managed (the least disturbed) followed by rangelands and farmlands (the most disturbed). The difference implies that cultivation and grazing by livestock appear to eliminate some termite species and it is believed due to the elimination of grass and straw grassed by livestock that lead to starvation of termite colony [6].

The relative abundance of termite also based on relative ecology of the areas. The number of termite genus encounters in a given area depends on land-use types. *Macrotermes* occurred 20 (32.8%) times out of the 61 total occurrences and 10 (16.4%) in rangeland out of its total 20 occurrences. *Macrotermes*, *Microcerotermes*, *Amitermes*, and *Microtermes* occurred in all of the land-use types. *Macrotermes* were the most abundant in rangelands, *Microtermes* in farmlands, and *Microcerotermes* in protected lands [8, 6].

The prevalence of termites and level of damage of crops by termite in major field crops and range lands in Manasibu district, west Ethiopia indicates out of 150, Forty-five samples of termites were collected from damaged maize in 15 fields and 40% of the samples contained by *Microtermes* species [8]. Moreover, 15 samples from rangelands were included in the samples collected. The termite samples were identified to six genera, namely *Ancistrotermes, Macrotermes*, *microterms*, *odontoterms, pseudodacanthoherms* and *Trinervitermes*. Among them *Microterms* was encountered frequently in roots and stems of maize and stalks of sorghum, and it was also observed at base of roots of matured teff with 37.5% of occurrence while *pseudodacanthoherms* and *Macrotermes* are 24.4% and 17.8% of occurrence in said crops respectively.

The seasonal distribution of Mound-less termites (*microterme*) prefer the Adoolleessa (cool dry season) and the onset of rain at the end of dry season (Bona-Hagayyaa). After the first rain showers, moundless termites invade the ground immediately. Long showers wash the roots and feeding holes of termites there by eliminating them from the ground [30].

3. Biology

Termites are small (4 to 15 mm long) and variable in color from white to tan and even black [24]. They have three-body parts: head, thorax, abdomen, and six legs. Termites have different looking individuals (called castes) living together in the colony. The largest individual is the queen [19, 18]. Her job is to lay eggs, about thousands per a single day. A king is always by her side. Other individuals have a large head with powerful jaws, or a bulb-like head that squirts liquid. These individuals are called soldiers. But the majority of the termites in the colony are called workers. They toil long hours tending to the queen, building and maintaining the nest, or gathering food, and feeding the young, which are called larvae.

Unique among social insects, termites' workers can be male or female. Some individuals develop wing buds become longer. Finally the nymphs develop into the fully winged adult, the future kings and queens. They vary in color from black to pale brown and the wings are opaque grey to black. The timing of swarming varies depending on species but usually occur after rainfall. In tropical habitats around the world termites, and the large earthen mounds they can build, are very conspicuous. These mounds are air-conditioned and may contain millions of individuals [10].

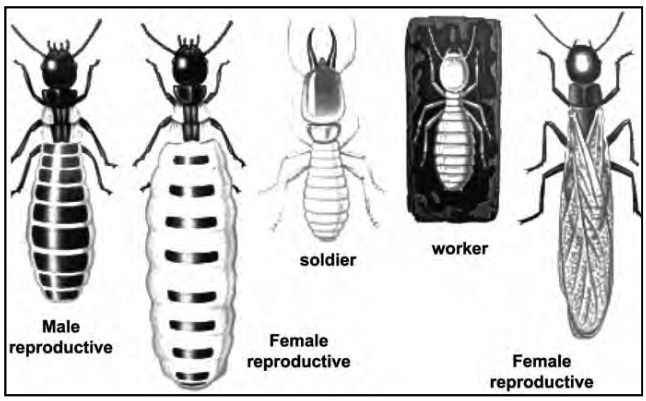

Figure 1. *Castes of termites [25, 18].*

3.1. Life Cycle

The termite's life cycle can result in three different types of termite or caste types. The three types consist of reproductive, workers, and soldiers. The life cycle contains an egg, young termite larvae or termite nymph, older nymph, worker, soldier, pseudergate, drone, and queen. This is a typical social insect system allowing for proper labor division [10]. Once a termite egg amongst countless thousands of others hatches, it is then called termite larva or larvae. The larva can become one of the three castes i.e worker, soldier, or a secondary or supplementary reproductive termite. This happens based on social, environmental, and termite pheromone cues. The larva then molts until it reaches maturity, which usually takes three molts. The larva can become a worker or soldier and its life cycle is over until it dies. The larva also could become a reproductive alate or secondary reproductive, where it goes on to reproduce and become a king or queen termite for another colony [13]. The queen has the longest life, spanning on average from 25 years. The other types of termite's life span vary from 12 to 24 months.

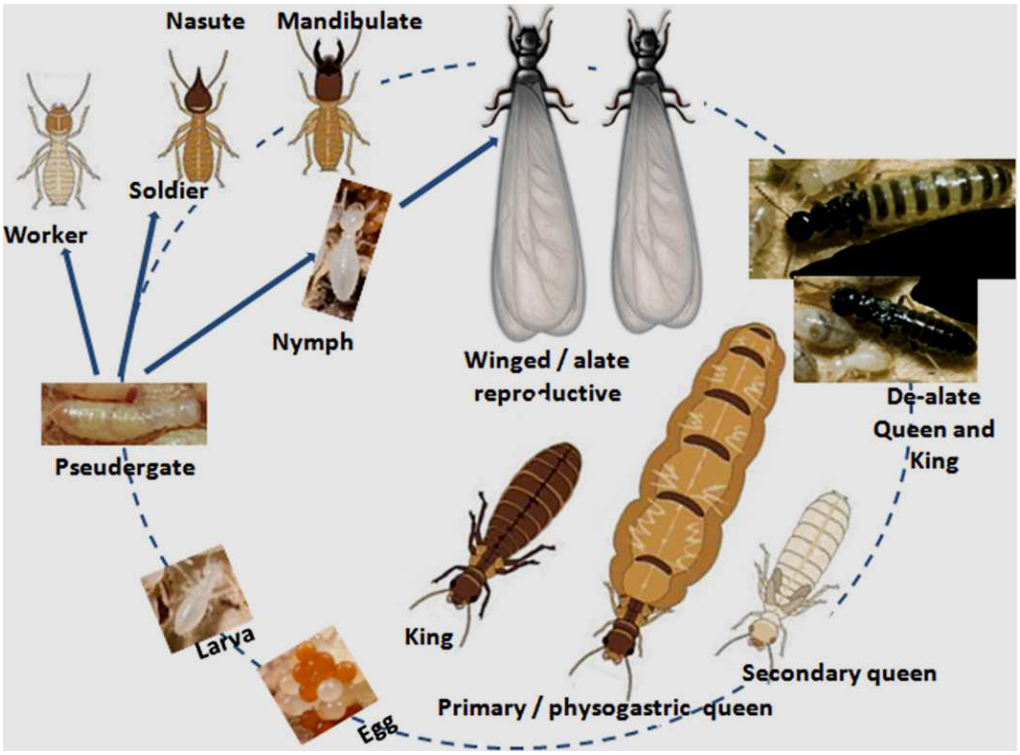

Figure 2. *Termite life cycle (Adopted from [5]).*

3.2. Reproduction

Likewise other organism, termite reproduce and replace itself for continuing it generation. As reproduction behavior, King and queen termites swarm in the summers in large groups of thousands in search of a mate [21]. The two mates have a mild courtship dance, and then begin to start their own colony. The male or king shares the labor with the queen as she is fertilized and ready to begin having baby termites. The first year of laying eggs the queen can have anywhere from a hundred to thousands of eggs a day [10]. The two care for the first few generations until there are enough young or workers.

When hatched into larvae, the young termites can become workers or soldiers depending on the pheromones and temperatures the eggs are exposed to. The workers are the sole providers in the colony's division of labor and it relies on them to care for all of the feeding, maintains order of the young and developing babies, and foraging. The workers and soldiers can be male or female; it doesn't matter because both are sterile [34]. The population of the colony will continue adding massive numbers for about five years, and then the queen will have her first reproductive alates, or young kings and queens. They will mature and prepare to swarm and leave to start another colony in the summer. The cycle continues over and over.

4. Ecology

Ecology of pests in general and termite in particular is all about the behavior of pests in related to own behavior and interaction with other organisms. Foraging and nesting mechanism and soil mounding as mechanism of nesting plus feed searching ways makes termite specific to other soil insects. Termites have soft cuticles, and do not inhabit cool or cold habitats. There are three ecological groups of termite damp wood, dry wood and subterranean. Damp wood termites are found only in coniferous forests, and dry wood termites are found in hardwood forests; subterranean termites live in widely diverse areas (Anynomous, 2014).

One species in the dry wood group is the West Indian dry wood termite *(Cryptotermes brevis)*, which is an invasive species in Australia. Both damp wood and dry wood termites prefer to feed on dead plant materials in the form of wood, leaf litter or soil, buildings, crops or plantation and forests using their mouth parts modified for chewing. They damage buildings, flooring, carpeting, art work, books, clothing, furniture and valuable papers [33]. Subterranean termites are ground-inhabiting social insects living in colonies and feed on dead parts of trees but are not known to attack live trees. Geographically, termites are mostly limited to the tropical and subtropical ecosystems, roughly found between 50° north and south with the greatest biomass.

Termites build up different sizes and structures of mounds and nests to house the entire colony. Ground termites usually build mounds with various sculptures, whereas arboreal termites construct nests on trees that provide a protected living space and water conservation through controlled condensation, in which nursery chambers exist deep in the nest where eggs and in-star larvae are tended. The structure of mounds is reasonably complex that the thin end of it faces towards the sun at its peak intensity allows termites to stay above ground [33].

The column of hot air rising in the above ground mounds helps to drive air circulation currents inside the subterranean network to distribute required temperature for those species cultivating fungal gardens and even for those spending much energy in maintaining the brood within a narrow temperature range (±1°C) over day [31]. In tropical savannas, the mounds may be very large with an extreme of 9m high like the conical mounds constructed by some species in well-wooded areas or 2–3 m would be a typical size, whereas the shapes range from somewhat amorphous domes or cones usually covered in grass and/or woody shrubs to sculptured hard earth mounds or a mixture of the two [2].

The study conducted at pastoralist land of Borana, the mound-less termites (*microtermes*) species, which are relatively new to the study area, are the most serious types in destroying everything of the rangelands. Even if it exist relatively in few quantity and new to range land ecology could cause a serious problem because of range land is most of grass land that is preferred by mound-less termite [30].

5. Yield Losses

Termite cause wide spread damage to a great variety of crops in tropical Africa. In Africa at large and Ethiopia in particular, the most important termite genera are *Macrotermes, Odnotermes, Pseudocanthotermes, Ancistrotermes* and *Microtermes* [27]. The damage can occur from seedling to harvest and usually occurs every year, as termites form more or less stable populations and foraging by various combinations of several species occurs throughout the year. In addition to direct loss of yield termite could also cause indirect loss by causing damage to building and house.

According to preliminary studies on damage of termite on rural house in central rift valley of Ethiopia on 58 home owners, 81.4% of surveyed house where infested and only 8.6% of house where free of termite infestation [6]. The cost for repair of damaged house and building is therefore the indirect loss from termite infestation. The studies at pastoralist site of Borana reported that If the termite invasion continues, it would be hard to find productive rangeland in the coming few decades in or around the study area. Pastoralists were asked about the termite situation in the past 20 years and responded that it was good in terms of its expansion. More than 70% of the respondents agreed that termites have impact on copping strategies of drought by destroying conserved feeds [30].

However, these days the situation seems worse; termites have invaded much of the rangelands. The indirect loss from termite is damage on grass and buildings. The damage of eucalyptus stands by termites including its seedlings at Pastoralists site of Borana, Oromia regional state of the country is also reported. Termites have the potential to completely damage big trees over a long period. Termites' mounds are reported to be one of the problems in the rangelands. No grasses grow near the mounds and as a result pastoralist travel from place to place in search of feed for their cattle [27]. The work from crop land, Mean percent of damaged maize, teff and sorghum, by termites (16.6%, 29.8% and 1.5%) respectively in Western parts of country, Oromia regional state of Manasibu districts only [8].

Table 1. *Yield loss due to lack of termites management and variation of yield response by different botanicals, chemicals control and untreated check of hot pepper.*

No	Botanicals against termites' damage on hot pepper [15] (at Baco, Oromia)		
	Treatment	**Dry Yield (q/ha)**	**Stand count at harvest**
1	*Azradrachta indica*	13.82	335
2	*Maesa lanceolata*	16.52	344
3	Diaznon 60% EC	16.95	345
4	Untreated check	6.62	241

Table 2. *Yield loss due to lack of termites management and variation of yield response by different botanicals, chemicals control and untreated check of Teff.*

No	Teff yield evaluated under different treatment [30] at Najo, Oromia		
	Treatment	**Yield (q/ha)**	**biomass**
7	Dailocus lablab	6.85	74.07
8	Chomo grass	5.89	60.44
9	Sweet lupine	6.44	57.78
10	Alfalpha	5.97	59.56
11	Sunnhamp	4.74	51.70
12	Cow pea	4.31	40.89
13	Durus ban 48% EC	3.05	41.34
14	Cattle manure	5.06	57.63
15	Control	2.83	34.94

6. Management Method

Management of termite is not as easy as management of other crop pests due it is hidden nest under the ground. The effectiveness of termite management depends on the distribution, ecology of termites and choice of efficient management techniques. The most commonly known management techniques are reviewed below; where integrated management techniques are environmentally and ecologically recommendable.

6.1. Biological and Botanical Extracts

Biological and botanical control is the use of living organism and plant preservative to control the pests that interfere with human wants [7]. Termites can be controlled by using natural predators such as *Metarhizium anisopliae*, and *Beauveria bassiana* [16]. Application of Metarhizium anisopliae (Metch Sorok Strain ICIPE 30) granules at planting of maize crop significantly decreased termite damage in maize fields which eventually reduced plant lodging and escalated maize yield [20]. Although application of fungus at planting targeted *Microtermes*, the treatment was also successful in preventing damage from *Macrotermes* populations which usually attack plants during maturity [11].

Seven different water extract botanicals were evaluated for their mortality rate of against termites under laboratory condition at Ambo Plant Protection Research Center, water extracts of tobacco leave (*Nicotiana tabacum*), Birbira seed (*Militia ferruginea*) and Endod leave (*Phytolacca dodecandra*) caused 100% mortality after 24 hours the same as the Standard check (cloropyrifos 48% E.C) and Pyrethrum E-185 flower (*Chrysanthemum spps*) caused as an average 91.25% mortality on both worker and soldier termite and non significantly different when compared with the Standard check, but highly significant differences were observed with the control check [27].

6.2. Chemical Control

Diaznon 60%EC (2,500 ml/ha) is a good management option for reducing infestation of termite especially for *Microterms* species which is very severe during the wet season [15] (Ibrahim and Demisse, 2013). The highest stand count of hot pepper where recorded with treatment of Diaznon 65% EC (50.50 ± 0.69) which is not significantly differ from botanicals *Maesa lanceolata* (54.00 ± 1.24) and *Azadrachta indica* (52.67 ± 0.95). In western Ethiopia, Diaznon 60% EC at 2 l/ha and Chlorpyriphos (pyrinex) 48% EC at 2.5 l/ha applied as soil treatments at the vegetative and flowering stages of hot pepper reduced termite damage and increased pod yield. Applications of chlorpyrifos at vegetative stage and Diaznon during transplanting were found to be effective [4].

6.3. Destruction of Termitaria

The term termitarium indicates soil room constructed by termite colony known as Mounds. Density of mounds is directly proportional to the quantity of vegetation consumed by subterranean termites in the semi-arid ecosystems. This is possibly because the majority of the pest termite species nest in epigeal mounds (termitaria). In such environment farmer's dig out the entire mound using locally available farm implements (e.g. hand hoe) until the queen is reached and removed. As the mound is dug out, the colony is exposed to direct sunshine rays leading to desiccation since they lack cuticles to protect them from heat [23].

In Ethiopia the same practice is known likewise in Uganda and additionally Mound flooding is also common practice to manage the infestation of mound building termite [4], it could be due to the reason of suffocation and as such aeration of soil is reduced which finally lead to death of colony. In contrary Killing queens in mounds or nests is not a solution to eradicate termites, because the stand by females from the colony may instantaneously replace the dead one within 24 h [33].

6.4. Use of Animal Excreta

The use of animal excreta is part of cultural practice in management of termite. It is non-synthetic termite management options; the use of cover crops and cattle manure could be as a major element of this strategy [30]. Seven different green manure, one synthetic insecticides and farmer practices were evaluated against termites under field condition at Nejo sub-site of Holeta agricultural research center during 2015/2017 cropping seasons, Ethiopia.

Accordingly green Manuring by different legume crops and chomo grass for termite management on acidic soil under teff production with *Dailocus lablab*, *Lablab purpureus* (8.53qt/ha), *Chomo grass*, *Brachiaria humidicola* (7.24qt/ha), and sweet lupine, *Lupinus albus L.* (7.68qt/ha) showed higher

grain yield and highly significant differences were recorded in terms of harvest index in both years and reduced termites' infestation. Cattle manure showed significantly higher harvest index ranging from 16.1 to 4.1 followed by *Dailocus lablab* and sweet lupine. Adding cattle manure and green manuring not only adds additional organic matter to the soil but also provides feed for the termites and confuses their attention. In area with complex environmental problems (acidity and termite infested) solve cropping system should consider environmental issues [30].

According to studies by [22], manure reduces termite damage on pasture and it serve as alternative food resources to termites, hence relieving pasture of termite attack; enhances proliferation of entomopathogenic organisms (termite enemies) which check the activity of termites, and enhances soil fertility and thus boosts plant vigor making it less vulnerable to various forms of shocks.

6.5. Integrated Termite Management

Integrated termite management is using of all possible combination of available termite management techniques [26]. For example, a field study was conducted to evaluate the pesticide efficacy of eleven botanical plants and Diaznon 65% EC against termites on hot pepper at Bako, Western Ethiopia during the 2005, 2006, and 2007 cropping seasons, the use of *Maesa lanceolata* and *Azadirachta indica* with Diaznon promoted as part of an integrated management program of termite on hot pepper [15].

The standard Diaznon 65% EC, *Maesa lanceolata* and *Azadirachta indica* give dry pod yield of 4.09±0.81q/ha, 4. 29±0.81q/ha and 4.67±0.85q/ha respectively which is significantly more yield than untreated one (2.09±0.19q/ha). The plant stands count with the same treatment 50.50±0.965, 54±1.24, 52. 67± 0.95 respectively which give more significant difference among the rest of eleven evaluated botanicals of *Chenopodium spp, Croton macrostachyus, Tagetes minuta, Datura stramonium, Vernonia amygdalina, Phytolaccado decandra, Nicotiana tobaccum, Shinus mole, Ficus vasta.* Therefore they recommend that as the combination of chemicals and those botanicals could boost the effectiveness management and the yield return could also increase than their individual applications.

The Integration of Cultural, Botanical, and Chemical Methods of Mound Treatment on Termites (*Macrotermes subhyalinus* Rambur) Colonies in Ghimbi District of western Ethiopia, indicates the combination of integrated management; Queen removal + *M. Lanceolata* leaf powder + chlorpyrifos 6 ml/mould, queen removal + chlorpyrifos 6 ml/mould, and chlorpyrifos 12 ml/mould resulted in colony destruction, and reduced damage to crops and wooden materials significantly [32]. Queen removal as a component of integrated management is effective and eco-friendly. They conclude that mound destruction using queen removal and lower rate of chemicals can be used for the management of termite. Moreover, ITM offers greater prospects for enabling termites to play important positive roles in agro-ecosystem functioning while reducing the damage they inflict on crop and livestock production [22].

7. Conclusions

Termite is social insect that live in group and share duty among their castes. Even if termites are found on all continents except Antarctica, Habitats are the heaviest in the tropic regions, subtropics, and warmer climate regions. *Microtermes spp* are common in tropical area specifically it cause huge loss to crops and range land grass as reported by different people across the globe. Termite species diversity and distribution vary from continent to continent and also it varies from one country to others within the same continent. Ecologically, termites are classified as damp wood, dry wood and subterranean termites. Damp wood termites are found only in coniferous forests, and dry wood termites are found in hardwood forests; subterranean termites live in widely diverse areas.

Termites have both negative and positive impacts. The positive advantages are that they are helpful in decomposing hard soil and let air to enter deep in the ground for further decomposition, nutrient recycling and create favorable shelters or habitat for reptiles and others by building mounds either above ground or deep into the ground. Some authors reported that people have eaten termites in many cultures throughout parts of Asia, America and Africa and are sources of diet and can replace the future food.

The negative effect of termites outweighs the positive effects; hence, minimizing the population is important for human beings to keep resource from termite damage. So, appropriate management practice is very essentials to escape from loss due to termite damage. The control technique of termite could vary according to environment, ecology and species of given termite. Generally, like wise any other pest, IPM technique is available for this termites. Therefore farmers across termites' prone area must be aware of it and should take appropriate control measures.

8. Research Gaps

In Ethiopia, where high density of epigeal termite mounds is found, little systematic studies were done to know the termite fauna. Despite of this, effect of ants on termites in the area as biological control and the impact of continuous soil cultivation on establishment of new colonies and colony size need further research. However little is done about the species composition of termite in other parts of Ethiopia and little is done around central rift valley that need a future concern. It is investigated queen removal is one of the mechanism of controlling termite and the chemical integration after the removal of queens, However, the rate of the chemical to be used after queen removal were not studied very well and to make it more environmentally friendly and economically affordable.

Other research gap is the absence of economic threshold level that have been not worked so far for *microterme* species in Ethiopia, therefore it need attention to establish economic

threshold of termite for agricultural produce. Even if yield loss is evaluated by different people, the number of termites and number of termite colony or termite mounds per square meter of land that lead to economic injury level is not well studied in Ethiopia.

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