Research Article

Termites Onslaught in Pakistan: An In Depth Review of Agricultural Impacts

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Abstract | Pakistan faces considerable losses in the field of agriculture every year as a result of termite activity. Numerous crops, particularly sugarcane, cotton, and wheat, are severely damaged by termites, resulting in substantial economic loss. Termites can potentially inflict significant agricultural losses, ranging from 20% to 45% of the harvest yield. Termites are also known to cause damage to stored food, wooden objects, household furniture, paper products, and various synthetic materials. They can attack both buried and above-ground parts of plants. They bite and chew on tubers, young and old leaves, stems, lower branches of the plants, and peanut seeds. Termite infestation is a considerable problem in the livelihood of the farmers of Pakistan. Termite swarming is a major problem and revenue constraint in the area, destroying crops in the field and store. Forests and orchards are rarely termites free, particularly when conditions are favourable for termites, such as drought. Furthermore, pasture lands used for grazing are susceptible to termites, leading to an acute shortage of animal feed. In this review, we tried to reveal all about the damages of termites in agriculture of Pakistan.

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Introduction

Termites are known as social insects that live in colonies (Sillam-Dusses *et al.*, 2023; Eyer *et al.*, 2023), and are often called as white ants (Shinozuka and Roy, 2024) but they are not white ants due to difference in their classification as termites belongs to order Isoptera while ants belong to order Hymenoptera (Wang *et al.*, 2024; Das *et al.*, 2023; Grimaldi and Engel, 2005). Termites have variety of species and this tiny creature has diversity in their individuals (Pequeno, 2024; Bignell and Eggleton, 2000; Abe *et al.*, 2000). Termites have 170 genera and 2600 species, out of which 300 species are of great importance (Ridout, 2023; Ibrahim and Adebote, 2012).

Isopterans can be categorized into 3 groups on the basis of their habitat, i.e., dry wood, damp wood and subterranean termites (Mogilicherla *et al.*, 2023; Baker and Marchosky, 2005). The termites that grow on fungus are most destructive than those which live in the soil (Ahmed *et al.*, 2004). Some species of termite's attack on fauna, there number is almost 50 (Shahid and Akhtar, 1992; Akhtar and Shahid, 1993). The most marvelous feature of termite is the damage to crops, wood and buildings (Hassan *et al.*, 2024; Ibrahim and Adebote, 2012; Khan *et al.*, 2020).

Termites play a significant economic role within the arena of economic entomology, as their destructive impact on buildings, particularly in developed countries of America and Asia, experiences substantial costs (Neoh and Lee, 2023; Krishna and Mkondiwa, 2023). The financial cost of the harm caused in these countries reaches millions of pounds. The degree of damage inflicted upon dwellings by termites is comparable to that caused by natural disasters and fires within a single year. Developing countries often face challenges related to the deterioration of infrastructure, including the damage inflicted upon the dwellings and agricultural fields of impoverished farmers (Govorushko, 2019).

In some villages of India and Egypt termite damage have been reached to such extent that inhabitants are forced to move to other areas. Termites have also been known to attack old temples in Asia (Pearce, 1997; Hamra *et al.*, 2022). The density of the termite population is dependent on the soil cores (Santhoshkumar *et al.*, 2024), whilst the variety of termites is dependent on the foraging population of termites in the soil as well as the trees that are present in the region (Graham *et al.*, 2024).

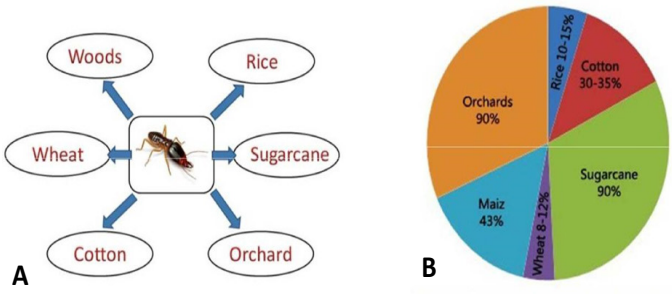

Figure 1: *A: Destruction of termite to different agricultural crops in Pakistan; B: Representation of termites destruction in Pakistan.*

Pakistan is an agricultural country; crops are backbone of Pakistan (Bahar *et al.*, 2023). Termites have adverse impact on agricultural crops, forest trees and wood components. Worldwide 300 termite species have been recorded as pest (Rasib *et al.*, 2023; Manzoor, 2011a). There are number of agricultural crops that are affected by termites, for example sugarcane, maize, wheat, agro ecosystem, wood and cotton etc. (Figure 1A, B).

Destruction of termite in woods and agro-ecosystem

Forests are main source of wood and wood products in Pakistan. Wood is a renewable natural resource and now a day's trend is more towards wood products in every field of life (Sertolli *et al.*, 2023). Wood is mostly used for constructions i.e., building interior and furniture. Customers require high quality wood, but damage by termites disturbs its quality physically and biologically. It is imperative to ensure the preservation of wood and wood products across many stages, including manufacturing, storage, transportation, and utilization (Uzunovic *et al.*, 2008). At the time when wood cut downs freshly, there is minimum chance of termite attack, but as time passes on heavy infestation of termite can be seen. Mostly larger wooden logs are infested heavily by termite but when humidity level is high, wooden logs show high level of devastation (Van Acker *et al.*, 2023).

Subterranean termites always prefer to live in larger wood logs in forests because larger wood logs provide them more food and shelter. Termites are not easily visible in large wood logs unless they completely destroy the entire wood log (Wang and Powell, 2001). It was observed that if there are larger dead wood logs, as the logs contain large number of cellulose so termite prefer such places and make colonies inside. In wooden logs, galleries of termites can be easily seen; it shows clear signs of termite feeding and infestation. Unfortunately, termites often stay hidden, which means that whole buildings and wood are destroyed, leaving only a thin layer of a wall to protect them from the outside world (Lenz *et al.*, 2001). Numerous species of termites cause extensive damage to unprotected structures and other wooden structures due to their natural aptitude for wood.

There are 28 pest species in the genus Coptotermes, which is the most of any genus (Su and Scheffrahn, 2000; Kumar *et al.*, 2023). Although only about 10% of dry-wood termites are pests, their presence affects wooden buildings and furniture in tropical, subtropical, and other regions. Damp-wood termites

exclusively target wood that has been exposed to moisture or soil. Dry-wood termites prefer warm climates and can infiltrate residential areas due to human activities, as they can be carried by ships, contaminated products, and containers. Termite colonies have been observed flourishing in heated structures situated in frigid regions. It is thought that some species of termites are invasive. For example, *Cryptotermes brevis* is the most widely adopted invasive termite species in the world (Evans *et al*., 2013).

Some species of termites also live-in mutualistic relationship with fungus, as *M. mycophagous* is a fungus growing termite, that can damage many crops and other related agricultural products and known as desert termite of Pakistan (Akhtar and Sarwar, 1993). Several districts in Punjab, including Bahawalpur, Multan, Layyah, Bhakhar, and Khanpur, have reported devastation from this species (Sheikh *et al*., 2005; Manzoor and Mir, 2010). It causes severe damage to the agricultural crops, residential structures, and trees (Iqbal and Saeed, 2013).

Termites commonly serve as ecosystem engineers in natural ecosystems, particularly in semi-arid environments where they frequently function as keystone species. Therefore, it is probable that termites have a significant positive impact by facilitating crucial ecological processes in agro-ecosystems, despite their well-recognized role as pests.

Destruction of termite in maize

Maize (*Zea mays*) is the world's third most important cereal crop, following wheat and rice. It is cultivated in tropical, subtropical, and temperate regions across the entire world. It incorporates 3.4% to the value added in agriculture sector and 0.6% to the Gross Domestic Product (GDP). The output of maize recorded a growth of 7.4 percent, reaching a total of 8.5 million tonnes, in comparison to the previous year's production of 7.9 million tonnes. The increase in production can be primarily due to an increase in land cultivation, the introduction of improved seed varieties, and greater economic incentives (Pakistan Economic Survey, 2020-2021). It provides both food and phytochemical substances. Phytochemicals are crucial in the fight against chronic illness. Phytochemicals like phytosterols, phenolic compounds and carotenoids are abundant in it (Shah *et al*., 2016).

In spite of that it was growing normally in Pakistan but in 21st century its yield going to decrease due to various reasons. Different pests are responsible for low yield. Among them, maize stem borer and sorghum shoot fly are dominant pests. Termites are also one of the major pests which destroy maize in Pakistan. Fungus growing termite *Microtermes*, *Allodotermes* and *Odontotermes* are few most attacking species in Africa and Asia (Hillocks *et al*., 1996). The damage caused by subterranean termites lowers production to 8-12% (Shults *et al*., 2021) (Table 1).

There is a correlation between soil management practices and the occurrence of damage to maize crops. Two species, *Microtermes obesiholmgren* and *Odontotermes obesus* (Rambur), damage 11–16% of the plants in all of the soil management approaches. The damage that caused by *M. obesi* was greater (9-14%) in plants than *O. obesus* (1-2%). An increase in tillage intensity within plots resulted in a corresponding increase in maize damage caused by termites. Nevertheless, the soil management interventions did not yield any statistically significant impact on the proportion of plants affected by termites. The phenomenon of termite-induced destruction becomes increasingly apparent towards the conclusion of the agricultural year, progressively intensifying as the plants undergo senescence. Termites cause the lodging of maize plants after senescence by causing injury to the roots and stems of the plants. Termite colonies are challenging to locate and eradicate, and an effective control method has not yet been developed. Throughout two seasons, various techniques of soil preparation that could destroy nests were assessed in the field. Deep chisel plough, deep mould-board plough, shallow chisel plough, rip, and rip-on-row were all examples of tilling methods (Smit and Berg, 2003; Summerton *et al*., 2023).

The effect of various tillage methods on lodging of corn plants was found to be highly distinct. The deep mould-board plough treatment, which turned and disturbed the earth to a depth of 0.30 m, greatly decreased the number of plants that got stuck. The deep chisel treatment stirred up the top 0.25 m of debris and also made it much less likely for the structure to become lodged. The treatments involving shallow chisel and rip on row exhibited the highest rate of lodging. However, deep tillage techniques are not regarded as a sustainable remedy for the detrimental effects of termites on maize. Termites are still a big problem in places where corn is grown, but

they haven't been properly controlled yet (Smit and Berg, 2003).

The lodging symptom is widely regarded as the most detrimental manifestation of termite damage in maize. Subterranean termites lower the yields of maize crops by 43% and wheat crops by 8–12%. A new survey says that termites are becoming a big problem for growing maize in Punjab, but it's not clear when and how to get rid of them (Ahmed *et al*., 2007).

Several types of termites eat corn, and the damage is worse during droughts or places where the rain falls in patches (Altieri *et al*., 2015). They hurt the stem's roots and base, which causes it to lodge. The damage keeps happening even on plants that have already fallen over. Damage can sometimes cause a loss of almost 100% of the yield, especially if it happens early on. After cobs have lodged, they are open to contamination, so damage that happens after physiological growth will cause grains of poor quality. Termites attack the crop at different stages of its growth, from seeds to full-grown plants. The badly hurt plants are easy to pull up by their roots and look dead and dry. If the roots are hurt in some way, the plants turn a yellowish color (Kumar *et al*., 2018).

Destruction of termite in sugar cane fields

Sugarcane is important economical and profitable crop of Pakistan. There are several factors that influence crop yield, including parasites (Raza *et al*., 2023). Termites are the most important and dangerous pest in agriculture. They are a big problem because they affect the growth of sugarcane and the quality of its juice. Destruction of termite lead to 90% damage in sugarcane fields (Rana *et al*., 2021; Ahmed *et al*., 2009).

Five species of Odontotermes and two species of Microtermes were reported in the field of sugar cane. In Khyber Pakhtunkhwa, Charsadda, and Nowshera were affected, as well as some areas in Punjab, such as Lahore, Gujranwala, and Gujarat. The worst damage was seen in July (Sattar and Salihah, 2002; Ahmed *et al*., 2009). Termites not only hinder the germination process but also negatively impact sugarcane quality during the germination stage, where losses can range from 90 to 100 percent. Two species of Microtermes and five species of Odontotermes were recorded in the K.P.K from Noshehra and Charsada districts (Ahmed *et al*., 2009).

The Xylophagous termites, *C. nordenskioeldi* and *N. coxipoensis* were the most abundant species in the sugarcane plantation. It was observed that individuals of *C. nordenskioeldi* feed mainly on dead sugarcane stems as well as on healthy stems and roots of plants. Individuals of these species are more in number and they alter the plant coloration and shorten their height. *N. coxipoensis* have individuals that feed generally on dead stems, but occasionally feed on living stems (less than 1%) which were previously attacked by larvae of *Diatraeasaccharalis* (Fabricius) (Lepidoptera: Crambidae). Additionally, it was noted that the diet of *A. nordestinus* specimens primarily consisted of fallen leaves and deceased roots, with occasional consumption of active roots. *A. nordestinus* has the potential to become a pest, whereas *N. coxipoensis* and *S. nanus* are unlikely to exhibit such behaviour. *S. nanus* individuals were observed to consume both fresh fallen leaves and living leaves. This behaviour was particularly noted when there was a scarcity of dead leaves on the soil, typically coinciding with the initial stages of sugarcane budding. In Manga Mandi, Punjab's District Lahore, sugarcane fields were found to have termite damage, which reduced the crop's yield by around 34.8%. The observed damage had a positive correlation with the height of the plant (Ahmed *et al*., 2009).

Macrotermes, termite pests, are pests that inflict modest amounts of destruction. Termites inflict damage on sugarcane in Central Africa, where they cause damage of 8.6–16.7% to the stem and 22-27% to the germination of sugarcane in the state of Nigeria. Termites in Central African nations, causing damage of up to 25% to sugarcane by 5–10%. These pests live their social based life in the dried stems and completes their life cycle that is shown in Figure 2 (Shang *et al*., 2024).

Biological, chemical, and cultural control are just some of the methods that have been used to get rid of termites. Farmers often use herbicides and other chemicals to control their crops, but these chemicals are costly and detrimental for the environment (Ahmad *et al*., 2007, 2021; Sattar and Salihah, 2001). The intercropping method works better against maize; it not only lessens the damage but also makes the termite-eating animals more effective (Umeh and Ivbijaro, 1999; Sekamatte *et al*., 2003). The intercropping method is thought to help keep termites under control in sugarcane fields (Table 1).

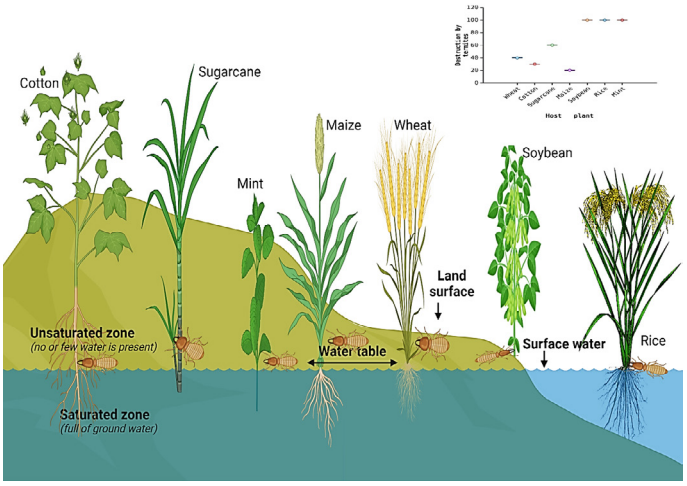

Figure 2: *Diverse destructive domains of termites with respect to water table and humidity.*

Destruction of termite in wheat fields

Wheat is Pakistan's most valuable cereal crop. Many people make use of it in various contexts (Mahmood *et al.*, 2019). The fact that it can be used in baking makes it a more significant and prominent crop than many others in the grain family. As a food source for humans, it provides carbohydrates and proteins, but it has a lot of problems because of biotic factors.

Insect pests are the most alarming factor and are major yield decreasing bodies. These pests damage wheat plants and its grain formation. Infestation to wheat is the major problem caused by these pests. Twenty-four species of insect pest's attack on wheat (Ranjith *et al.*, 2018; Singh *et al.*, 1998) out of all, termite is at first position not only in India but in South Asia. 16 species are observed which cause damage to wheat in India, two of them are very important; *Odontoter mesobesus* (Rambur) and *Microter mesobesi* (Holm) (Chhillar *et al.*, 2006). Termites damage the wheat after sowing and secondly when the plant is near maturity. They feed on roots and attack underground parts of plant. They continue to eat dead roots of plants for cellulose gain. They also attack on growing stems and plants which eventually become dead.

Termites do significant damage throughout both the seeding and maturity stages. They reduce the germination percentage by feeding on seed. Termites eat in a semi-circular pattern on the margins of the leaves of standing crops, causing the outer leaves to yellow and dry out first, then the interior leaves, and consuming the cellulose-containing plant tissues. Plants that sustain significant damage eventually dry out and become readily removed. Uneven plant spacing and seedling loss result in patchy looks. If there is partial damage to the roots, the plants will become yellow (Bajpeyi *et al.*, 2023).

The plant that is damaged by termite dries up completely, and is easily pulled out. At later stage, the damaged plants show white ears. Un-irrigated fields and the fields in which there is minimum un-decomposed manure, show heavy infestation by termite. The range of yield loss by termites lead to 43-80% in wheat (Sattar and Salihah, 2001; Chhillar *et al.*, 2006). According to recent survey, this loss reduces to 8-12% by the use of chemicals (Table 1).

A survey was carried out to check the destructive status of termites in wheat field, it was observed that termites do massive loss in different crops in Pakistan and wheat is one of them. Wheat is cultivated in all areas of Pakistan, but termites attack is mostly observed in arid and semi-arid zones like Layyah, Mianwali etc (Bug, 2015). Different six species of termite's attack in fields of bhakkar district are *Microtermes* spp., *Odontotermes obesus, Microtermes obesi, Coptotermes heimi, Microtermes mycophagus* and *Odontotermes guptai* (Manzoor *et al.*, 2011b).

Destruction of termite in orchards

Orchards are beneficial to human health as well as profitable for country. Pakistan is famous for its production to different fruits like mangoes, citrus, banana, guavas and dates (Shah *et al.*, 2022). Mango is the king of all fruits and is exported to other countries on larger scale. Orchards of Pakistan are damaged by different insects and termites also cause great damage to orchards that goes to an extent of 90%. Termites destroyed many of the orchards in Punjab completely (Akhtar and Shahid, 1989). This destruction has 3 major reasons:

- Hot season from April to July when temperature record is that it raises up to 45 °C
- Rainy season (August to September), when average rainfall is recorded as 46 cm.
- Mild season (October-March), when temperature decreases to 21°C (Akhtar and Sarwar, 1997).

Termites damage to fruity plants and fruit formation decreases to a considerable limit. They eat up roots of plants and bore into the stem, hollow the tree which automatically fell down. Garden trees are also a big source of oxygen and absorb carbon dioxide and clean as well as balance the environment. Garden tress also

Table 1: *Termites host plant, destruction and control methods (chemical and non-chemical).*

Host plant	Scientific name	Destruction by insects	Destruction by termites	Non chemical control	Chemical control	References
Wheat	Triticum aestivum	20-37%	20-40%. (6 to 40% in India)	Crop Rotation, Intercropping.	Chlorpyrifos, Imidacloprid, bifenthrin Insect growth regulators (hexaflumuron and fenoxycarb)	Pimentel *et al.*, 1997; Misra *et al.*, 2003; Roonwal and Chhotani, 1989; Chhotani, 1997; Sekamatte *et al.*, 2003; Singla and Singh, 1998; Mishra, 1999; Rana *et al.*, 2001; Manager and Singh, 2001; Santharam *et al.*, 2002; Singh and Singh, 2002a, b; Saroj-Jaipal and Singh, 2003; Singh, 2003; Ahmed *et al.*, 2007, Parihar, 1978.
Cotton	Gossypium herbaceum	5-15%	10 to 30%	Keep the crop properly irrigated, sprinkler irrigation	Imidacloprid @ 0.01% and quinalphos @ 0.05 % alternately at ten day interval.	Anonymous, 2010; Poul *et al.*, 2018; Anonymous, 2000; Mart, 2004; Makwana, 2018
Sugar-cane	Saccharum officinarum	20-25%	1-upto 60% 2-Losses by termite may be 90-100% at the germination stage.	Locate and destroy the termite colony by burning, Flood irrigation at the time of planting	Some insecticides, like chlorpyrifos, imidacloprid, and fipronil, come in both liquid and dry forms. They have been claimed as a way to treat setts in furrows before the first irrigation.	Bhatt *et al.*, 1996; Jaipal and Chaudhary, 2010; Bhagwati *et al.*, 2017; Salihah *et al.*, 1988; Singh and Singh, 2002.
Maize	Zea mays	30% (Wongo, 1996). 35%	Termite causes occasional yield loss	Crop Rotation, Intercropping.	Endosulfan 35 EC @ 3 g per kg, Fipronil granules, Chlorpyrifos granules	Sharma *et al.*, 2003; Panwar, 2005; Sekamatte *et al.*, 2003; Pradhan, 1969.
Soy-bean	Glycine max	11%Yield losses due to individual diseases/ insect/weed species ranges from 20 to 100%	50 to 100%	Screening, Fertilizer dose, Seed treatment, Sowing time, Seed rate and sowing, Use of Castor as trap crop for *tobacco* caterpillar and *Dhaincha* for girdle beetle.	Chlorantraniliprole 18.5% SC @150 ml/ ha for defoliators. Thiamethoxam 30% FS @ 10 kg/ha for white fly. Triazophos 40 EC @ 625 ml/ha for girdle beetle. Indoxacarb 15.8% EC @ 333 ml/ha for blue beetle and pod borer	Sekamatte, 2001; Sharma *et al.*, 2014.
Rice	Oryza sativa	Reduces yield up to 30%.Occasional outbreak of insect pests can destroy between 60 and 95 % of rice crop	Yield losses ranging from 50 to 100% have been reported by termites to rice crops	Sanitation, Planting and Harvesting schedule, Destructive tillage Proper fertilizer and water management, Handpicking, Netting, Flooding/ water stagnation avoids termite infestation Manual digging, collecting queen(s) and killing, Indigenous approaches for the management of termite and white grub in upland rice	Chlorinated hydrocarbons, Organophosphates, Methylcarbamates, Pyrethroids, All neuroactive chemicals, Rice insect pests of Pakistan and their control, Organo-chlorine insecticides for termite control.	Singh *et al.*, 2017; UNEP,2000; Yambao *et al.*, 1993; Pathak and Kehan, 1994; Mahapatro, 2011; Mahapatro *et al.*, 2011; Mahapatro and Sreedevi, 2014; Litsinger, 1994.
Mint	Mentha piperita	Oil yield of Mint may be reduced by up to 80% in infested fields due to pests (Floridotarsonemus)	Termite attacks have caused 50 to 100% losses of crops and tree stands in Uganda.	The utilization of botanical materials for insect pest management, particularly termite control, has a long history in African agricultural culture. Plants such as neem leaves and seeds have been used to control insect pests in one form or the other.	Organochlorine insecticides have been used to control termites, Acephate control for cutworms, loopers and mint aphids. Methomyl for cutworm, alfalfa looper and flea beetles.Propagate for Floridotarsonemus Malathion for control of mint aphids and adult flea beetles	Owusu *et al.*, 2008; Sekamatte, 2001; Saxena, 1986; Lowery and Isman, 1993; Logan *et al.*, 1990.

provide habitat to different animals, recycle ground water, replace soil nutrients and protect soil from erosion as shown in Figure 3. Hence these trees are attacked by termites, considerable reduction in yield is noticed (Nazir *et al*., 2016).

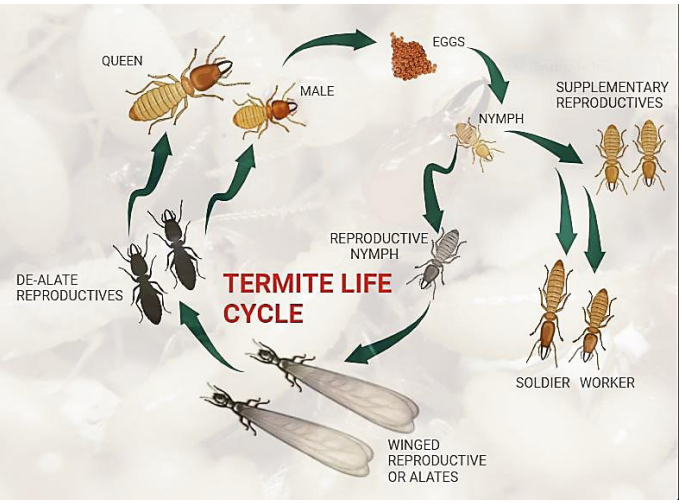

Figure 3: *Life cycle of termite.*

Termites also attack dry fruit trees like almond, walnut, chilghoza and pistachio that belong to nut family group in Khyber Pakhtunkhwa Pakistan. These fruits are very important economically that provide a very handsome amount of cash to owners. Since ancient times, these dry fruits have been consumed as one of the healthiest foods on earth (Ravan *et al*., 2009). These are a naturally occurring heart-healthy snack that is also delicious. These are highly nutrient dense, full of fibber and antioxidants, pistachios are calories rich nuts than any other nut. Termites damage such trees by eating roots and stems. Infestation caused by termites show a lot of harm to these trees and fruits. This damage ultimately reflects its impact on country's economy.

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Novelty Statement

This comprehensive review explores the multifaceted impacts of termite infestations on the crops in Pakistan, emphasizing the urgent need for innovative pest management strategies.

Author's Contribution

The contributions of the authors to the project were significant and varied. Saddam Hussain was responsible for crafting the original draft, while Muhammad Asrar Choudhary provided valuable supervision throughout. Usama Saleem took on the tasks of writing, reviewing, and editing, ensuring the quality of the content. Dilbar Hussain also provided crucial supervision. Muhammad Sohail Qadir and Muhammad Saleem conducted formal analyses, adding depth to the research. Rashid Ali played a key role in conceptualization and data curation. Additionally, Zeeshan Javed provided valuable assistance in revising the manuscript and conducting formal analyses. Finally, Mubshar Saleem contributed significantly to formal analysis, rounding out the collaborative effort of the team.

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Conflict of interest
The authors have declared no conflict of interest.

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