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EVALUATION OF THE EFFICACY OF A FUNGAL SUSPENSION OF THE FUNGUS BEAUVERIA BASSIANA LOAZDED ON GUM ARABIC IN THE CONTROL OF THE TERMITE MICROCEROTERMES DIVERSUS (SILVESTRI) UNDER LABORATORY CONDITIONS.

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Abstract. This study was conducted in 2026 to evaluate the efficacy of the fungus B. bassiana in controlling termite workers and to investigate the effect of adding an aqueous solution of gum arabic to the spore suspension in improving fungal infection efficacy under laboratory conditions. The results showed that the fungus was effective in causing infection and mortality, as mortality rates varied according to spore concentration, exposure duration, and treatment type. Fungal efficacy gradually increased with increasing concentration and prolongation of exposure. The concentration(1 x 108) spores/mL recorded the highest averages of dead workers and the highest mortality rates, particularly fourteen days after treatment.

The results also showed that adding the aqueous gum arabic solution to the spore suspension improved fungal efficacy compared with the spore suspension alone. Treatments containing gum arabic achieved higher mortality rates at all concentrations used, indicating that the use of gum arabic can enhance the performance of the fungal inoculum and increase biological control efficacy. Fungal infection was observed to develop gradually over time, reflected in the increasing numbers of dead workers and rising mortality rates until the end of the exposure period.

The results confirm that B. bassiana has promising potential for controlling termites and that improving the fungal inoculum formulation by adding natural adjuvants, such as gum arabic, can contribute to developing more effective and sustainable biological products, supporting their use in integrated pest management programs and reducing reliance on chemical pesticides.

Keywords: Beauveria bassiana; Termites; Gum Arabic; Biological Control; Mortality

Introduction

Termites are economically harmful and dangerous pests in many regions of the world, as they attack cellulosic materials in buildings, trees, and crops. These pests cause severe economic losses to timber in buildings, which necessitates great efforts and the expenditure of huge sums to prevent damage to homes and public buildings. Termites may attack wood anywhere within a building, from underground to the highest point of the roof. Detecting termites is often difficult due to their hidden nature, the complexity of the building structure, the location of the damage or the presence of termites in it, and the available techniques. Several methods have been used to detect and monitor the presence of termites in buildings, ranging from simple visual inspections to technical or technology-assisted methods, which vary in their prevalence and destructive capability (Hassan& Nanda,2024). This insect belongs to the order Isoptera:Termitidae, distinguished by the similarity of its forewings and hindwings, and characterized by its social life in colonies numbering from a few hundred to several million individuals. It is among the most advanced insect families, and to this day new species and genera of it are still being recorded in many countries of the world. (Donovan,etal,2001)

The use of chemical pesticides has contributed greatly to increasing food production and controlling pests. However, the excessive and indiscriminate use of these chemicals has led to many negative effects on human health and the environment, including the emergence of pesticide-resistant pests, water pollution, and the death of non-target organisms (Damalas, & Koutroubas,2018). Therefore, recent years have witnessed growing interest in developing safer and more environmentally friendly alternatives to chemical pesticides, such as biopesticides (Mitra, & Mandal,2011). Biopesticides are derived from natural substances and organisms capable of controlling pests and diseases (Friuli,etal.2020). Among these organisms, entomopathogenic fungi, which are microorganisms found in the soil, have gained widespread popularity as a promising alternative to chemical pesticides.This is due to their specialization in targeting insects (mainly through contact), their low toxicity to non-target organisms, and their environmental and health safety. What further increases the efficiency of using antagonistic fungi as pathogenic agents against termites is their rapid spread within the colony, as the infection of one individual from the termite caste, through its contact with other caste members, transfers the pathogenic agents since they are carried on the insect cuticle, [Jaronski,2023]. The fungus B. bassiana is at the forefront because of the biological characteristics it possesses that have made it one of the most widely used fungi in biological control programs, owing to its biological and environmental traits that have made it an effective agent in controlling many insect pests of economic importance. This fungus is distinguished by possessing a wide host range, as it can infect hundreds of insect species belonging to different orders, which gives it a great capacity for use in controlling a wide spectrum of agricultural pests and storage pests. The infection process begins with the adhesion of spores to the surface of the insect's external cuticle, then their germination and penetration using a combination of mechanical pressure and cuticle-degrading enzymes, such as chitinase, protease, and lipase, after which the fungus reaches the hemocoel, where it reproduces and produces a number of toxic secondary compounds, such as Beauvericin, Bassianolide, and Oosporein, which lead to suppression of the insect's immune system and disruption of its physiological functions, resulting in its death and then the appearance of white fungal growth on its surface; therefore, the disease resulting from it is known as white muscardine disease (White Muscardine Disease) . (Mascarin, & Jaronski,2016). B. bassiana is also characterized by a high degree of environmental safety compared with chemical pesticides, as it is considered an environmentally friendly biological control agent, owing to its limited impact on humans, vertebrates, and many non-target organisms when used according to recommendations, in addition to its role in reducing environmental pollution and lowering the risks of chemical pesticide residues. Moreover, the difference in its mode of action from conventional pesticides reduces the likelihood of resistance development in insects, which makes it an important component in Integrated Pest Management (IPM) programs. In addition, the fungus is distinguished by the ease of its industrial production and the possibility of formulating it as highly efficient commercial products, and it has demonstrated remarkable success in controlling many agricultural pests as well as soil and storage pests, which has made it receive increasing attention in recent studies and practical applications of biological control (Zimmermann,2007). To increase pathogenic effectiveness, researchers have explored the use of formulations based on biopolymers (Immediato,etal.2015). Biopolymers are naturally derived polymers that can be extracted from renewable sources such as plants, animals, and microorganisms. These materials are characterized by being environmentally friendly and biodegradable, and they can be used in pest control strategies to enhance the stability, adhesion, and survival of entomopathogenic fungi under field conditions. This is achieved by protecting these fungi from environmental stresses and providing a suitable microenvironment for their growth, survival, and effectiveness against target insects (Nicodemus,& Bryant,2008). Biopolymer formulations are being investigated as a potential solution to improve the field efficacy of entomopathogenic fungal biopesticides by reducing the initial amount of biopesticide required (such as the initial spore concentration) and the frequency of application, making these biopesticides more cost-effective. Moreover, the protective effect provided by biopolymers may contribute to extending the shelf life of products based on entomopathogenic fungal biopesticides. Biopolymer-based formulations are innovative techniques for delivering entomopathogenic fungi as biopesticides, making them a promising strategy in integrated pest management. (Friuli,etal.2021; Copping,2013) Among the polymers used in biological control is gum arabic, which is distinguished by its ability to act as a stabilizer, a binder, and an emulsifier, as the glycoproteins present in it contribute to binding to different surfaces, while the hydrated carbohydrate chains provide a protective barrier that increases the physical stability of suspensions. For this reason, gum arabic is considered one of the promising materials in developing biological formulations of entomopathogenic fungi, as it is expected to help improve the adhesion of spores to the surface of the insect body, reduce their loss during application, and maintain the homogeneity of the spore suspension (Aphibanthammakit,etal.2020) Although many studies are available that have addressed the use of entomopathogenic fungi, particularly B. bassiana, in controlling various insect pests, most of these studies focused on evaluating the efficiency of the fungus in its conventional form without improving its application formulation. Other studies have also addressed the use of gum arabic as a natural substance with stabilizing and adhesive properties in food, pharmaceutical, and biological fields; however, information regarding its effect on improving the performance of spore suspensions of entomopathogenic fungi remains limited. In addition, there are not enough studies clarifying the role of gum arabic in increasing the adhesion of B. bassiana spores to the body of the termite insect and the effect of that on mortality rates and the speed of fungal infection. Therefore, this study aims to fill this knowledge gap by evaluating the efficiency of the spore suspension supplemented with gum arabic and comparing it with the conventional spore suspension in controlling termites under laboratory conditions.

Materials and Methods

Source of the colony and its acclimatization in the laboratory

Individuals of the termite Microcerotermes diversus were collected from mature citrus and palm trees that showed severe infestations in the fields of Al-Alam district / Salah al-Din, for use in laboratory studies. For the purpose of obtaining sufficient numbers of workers, pieces of palm fronds moistened with a little water were used and then buried in the soil at a depth of (10–20) cm around the trunks of the infested trees for a period ranging from one to two weeks, to attract the maximum possible number of worker termites from the colony depending on the method of (Al-Jassani, & Al-Zubaidi,2015).

After that, the frond pieces containing the workers, in addition to clumps of the surrounding soil, were lifted and carefully transferred to the laboratory. The insect individuals were placed inside glass basins whose four sides were covered with aluminum foil, then covered from above with metal sheets to provide the dark conditions suitable for the insect’s activity.

The process of acclimatizing the colony individuals under laboratory conditions continued for a period of no less than seven days before proceeding with the various experiments. The experimental units (Petri dishes) were kept in complete darkness at a temperature of 28 ± 1°C and a relative humidity of 90 ± 5% in an incubator.

fungus isolate B. bassiana

A pure isolate of the fungus, identified by the Ministry of Science and Technology / Department of Agricultural Research and known by the code (2), was obtained. The fungi were cultured on liquid potato dextrose medium (PDB) to activate the fungus (Reda,etal,2022).

Preparation of the fungal suspension

Preparation of the spore suspension of the fungus by growing the fungi B. bassiana on 150 ml of medium (Emerson Yeast extract Soluble starch broth) in 250 ml glass flasks. The culture was incubated at a temperature of 25°C for 7 days and was shaken daily to distribute the fungal growth, then filtered by a piece of gauze. 1 ml of the filtrate, to which (Tween80) had been added at a concentration of (0.01%), was taken and placed on an Improved Neubauer Haemocytometer slide to count the spores and estimate the number of spores per unit volume, where the number of spores in each square of the four large squares located at the corners of the slide was counted. After that, their total number was divided by four to obtain the average number of spores in one square, then this result was multiplied by 1 × 104)the volume conversion factor (to obtain the number of spores in 1 ml of the fungal suspension (Goettel,1997)

For the purpose of obtaining a lower concentration than that, the following equation

was applied
required concentration

$$\text{volume (ml) taken from the stock suspension} = \frac{\text{Required concentration}}{\text{Original suspension concentration}}$$

original suspension concentration

Then the result is multiplied by the volume of the suspension required to be prepared, and thus the following concentrations were prepared: (1×10^{8}, 1×10^{7} ,$1x10^{6}$) spores / ml (Lacey,1997)

Preparation of An aqueous gum arabic solution

Gum arabic was purchased from a local market in Tikrit, Salah al-Din, Iraq, and was used in preparing the aqueous extract. The dried gum was ground using a toothed disc mill to obtain small-sized particles. The aqueous extract of gum arabic (1% w/v) was prepared by soaking 1 gram of the gum in 100 ml of distilled water for 24 hours, then filtering it. It was prepared fresh daily.

Preparation of the insect nutrient medium

The nutrient medium for the termite insect was prepared by mixing (50) grams of dried, sterilized fine sawdust to prevent contamination by fungi and bacteria with an agar solution at a concentration of (4%), by dissolving (4) grams of agar powder in (100). The agar solution was added to the fine sawdust with the aim of increasing the cohesion of the sawdust particles with one another, as well as providing the moisture level suitable for termite activity. (Al-Salihi,2006).

Study of the effect of different concentrations of the fungal suspension of B. bassiana on killing termite workers under laboratory conditions

A study was conducted to evaluate the effect of different concentrations of the conidial suspension of the fungus B. bassiana in causing death to termite workers under laboratory conditions, using direct spraying of the insect individuals with the conidial suspension and the conidial suspension mixed with a gum arabic solution.

1- Direct spraying method of the fungal spore suspension on the insect:

In this experiment, (12) sterile Petri dishes, with a diameter of (20) cm, were used, and the nutrient medium prepared in the laboratory, as previously mentioned, was spread in them. Then, 30 acclimated workers with their tunnels were transferred to each Petri dish (three dishes for each treatment representing three replicates). A volume of 5 ml of each concentration solution from these three concentrations was used by spraying it directly onto the dishes assigned to each concentration from a distance of 7–10 cm above each dish to cover the nutrient medium added to them. The dishes were closed and wrapped with aluminum foil to provide the darkness suitable for the insect, then left under laboratory conditions. The experiment continued for (14) days, and the numbers of dead insects were recorded and mortality percentages were calculated on days (7, 10, and 14) of the experiment period. The internal surfaces of the dishes were moistened with sterile distilled water to provide the required humidity (Krutmuang,2005). To confirm infection of the dead workers with the fungus, a group of dead workers was collected and placed in sterile Petri dishes, each 10 cm in diameter, lined with filter paper saturated with sterile distilled water. The dishes were incubated in an incubator at 25±2°C for two weeks to monitor the growth of the fungus B. bassiana .

Statistical analysis

The experiments were conducted using a completely randomized design (CRD) to study the effect of concentration, the method followed in treatment, and the time periods, and their effect on mortality percentages. Significant differences between means were also compared using the least significant difference (LSD) test at the 0.05 probability level to compare the results. The SAS statistical program was used in the statistical analysis.(Gomez, & Gomez,1984)

Results and Discussion

Table (1) shows the effect of spraying with a conidial suspension of the fungus B. bassiana alone or mixed with an aqueous solution of Arabic gum on the percentages of termite worker mortality seven days after treatment. The statistical analysis results showed significant differences ($P \leq 0.05$) between the two treatments and the concentrations used, as the mean numbers of dead workers and mortality percentages gradually increased with increasing conidial suspension concentration. The mean numbers of dead workers in the conidial suspension spraying treatment were 10.0, 15.0, and 19.0 workers, corresponding to mortality percentages of 33.3, 50.0, and 63.3% at concentrations of 1×10^6, 1×10^7, and 1×10^8 spores/ml, respectively. Meanwhile, the treatment involving conidial suspension mixed with aqueous Arabic gum solution recorded means of 13.0, 18.0, and 21.0 workers, with mortality percentages of 43.3, 60.0, and 70.0% at the same concentrations, indicating the superiority of the treatment containing Arabic gum from the early days of exposure. The statistical letters also indicated significant differences among most means, particularly at the highest concentration, which achieved the highest mortality efficiency. These results indicate that increasing the concentration of the spore suspension increased the likelihood of the insect becoming infected by the fungus, as the higher number of spores per unit volume increases the probability of their contacting the insect's body surface, thereby increasing the number of spores capable of adhering to the cuticle and initiating germination. The adhesion stage is considered one of the first essential stages in the fungal infection cycle, as infection cannot begin unless the spores are sufficiently fixed to the insect's body surface. Holder and (Holder, & Keyhani,2005) demonstrated that infection success depends largely on the efficiency of spore adhesion to the insect surface, and that increased adhesion raises the likelihood of germination and penetration, which is reflected in higher mortality rates. The infection process begins after the spores adhere to the insect surface, where they germinate, forming a germ tube that penetrates the cuticle with the aid of a group of hydrolytic enzymes, such as Proteases, Chitinases, and Lipases, which break down the proteinaceous, waxy, and chitinous layers of the insect body, allowing the hyphae to enter the hemocoel and spread throughout the body, followed by the secretion of secondary toxins that disrupt the insect's physiological processes and ultimately cause its death. (Ortiz,& Keyhani,2013) demonstrated that the success of these stages depends primarily on successful spore adhesion, which explains the notable increase in mortality rates when gum arabic is used.

It is noted that adding the aqueous solution of Arabic gum to the spore suspension led to a clear increase in mortality rates at all concentrations compared with the spore suspension alone. This may be explained by the role of Arabic gum as a sticker, which helped fix the spores to the surface of the worker bees' bodies and reduce their loss after spraying, thereby prolonging their persistence on the cuticle. This provided a greater opportunity for germination, formation of a germ tube, and subsequent penetration of the cuticle layer. The higher mortality rates in the treatment containing Arabic gum indicate that improving spore persistence on the insect body contributed to increasing the efficiency of fungal infection. (Prasad ,etal.2022).

indicated (Sajap, and Kaur.,1990) that the infection process in termite workers by the fungus begins after the spores adhere to the insect's body surface and germinate. A germ tube then forms, penetrating the cuticle to reach the internal tissues. The fungus subsequently spreads gradually throughout the insect's body, first infecting the fat bodies, followed by the muscles, nervous cells, and then the cells lining the alimentary canal and gizzard. Infected workers were observed to die within 36–48 hours after infection, while the fungus had spread to most internal organs after 72 hours. After approximately 100 hours, fungal hyphae begin to appear on the cuticle surface, followed by the formation of chains of conidia about 120 hours after infection, indicating completion of the infection cycle and the fungus's readiness to spread to new hosts. These findings also agree with those reported by (Milner,2001), who demonstrated that increased contact between spores and the insect's body surface improves the efficiency of fungal infection and accelerates mortality. In addition, increasing the fungal inoculum density raises the likelihood of successful infection, which explains the gradual increase in mortality rates recorded in the present study with increasing concentration.

Table (1) Percentage mortality of termite workers when using different concentrations of the two treatment types by spraying over an exposure period of (7 days)

Treatment	Concentrations	Total	1	2	3	Number Mean	Percentage (%)
Spraying with spore suspension	$1X10^6$	30	9	10	11	**10.0 C**	33.3
Spraying with spore suspension	$1X10^7$	30	14	15	16	**15.0 B**	50.0
Spraying with spore suspension	$1X10^8$	30	18	19	20	**19.0 A**	63.3
Spraying spore suspension with gum arabic	$1X10^6$	30	12	13	14	**13.0 B**	43.3
Spraying spore suspension with gum arabic	$1X10^7$	30	17	18	19	**18.0 A**	60.0
Spraying spore suspension with gum arabic	$1X10^8$	30	20	21	22	**21.0 A**	70.0

The identical capital letters in each column mean there is no significant difference between them. LSD at P=0.05

The identical capital letters in each column mean there is no significant difference between them. LSD at P=0.05

The results of Table (2) showed that, ten days after exposure, mortality rates continued to increase in all treatments compared with those recorded after seven days. The mean numbers of dead workers in the treatment sprayed with the spore suspension were 15.0, 20.0, and 24.0 workers at concentrations of 1×10^6, 1×10^7, and 1×10^8 spores/ml, respectively, corresponding to mortality rates of 50.0, 66.7, and 80.0%. Meanwhile, the means in the treatment sprayed with the spore suspension mixed with the aqueous solution of gum arabic increased to 18.0, 23.0, and 27.0 workers, with mortality rates of 60.0, 76.7, and 90.0% at the same concentrations, with significant differences ($P\leq0.05$) between the means. This indicates that increasing the exposure duration contributed to enhancing the fungus's efficacy in causing infection, while the treatment containing gum arabic continued to outperform the spore suspension alone. It is also noted that the treatment with the spore suspension mixed with the aqueous solution of gum arabic maintained its superiority at all concentrations, reaching a mortality rate of 90.0% at the concentration of 1×10^8 spores/ml, compared with 80.0% for the spore suspension alone.

The notable increase in mortality rates after ten days is attributed to the fact that the fungus is no longer confined to the infection stage; rather, it has become established within the insect's body, allowing its continued growth and reproduction in the hemocoel and internal tissues. This gradual colonization leads to increased production of cuticle- and tissue-degrading enzymes, as well as the accumulation of secondary metabolites and mycotoxins that contribute to weakening the insect's immune system and causing increasingly severe physiological disturbances. Consequently, mortality rates rise as the exposure period progresses. The virulence of entomopathogenic fungi does not result from a single factor; rather, it represents the cumulative effect of penetration, reproduction within the host, and the secretion of enzymes and toxins that act simultaneously until the infection reaches a stage resulting in the insect's death (Wang,2021)

The notable increase in mortality rates after ten days is attributed to the addition of gum arabic to the spore suspension, which provided more favorable conditions for maintaining spore efficacy on the workers' body surface, allowing a greater number of them to successfully complete the infection stages. As the exposure period progressed, the number of effective infections increased, leading to the expansion of fungal colonization within the insect's body and the gradual accumulation of its pathogenic effects, until the insect's ability to resist infection became lower compared with the treatment containing only the spore suspension. Furthermore, the continued growth of the fungus inside the body is accompanied by the ongoing secretion of hydrolytic enzymes and secondary metabolites, which cause increasing physiological disturbances in the insect's tissues. This explains the clear increase in mortality rates at this time point (Islam,etal,2021), and accounts for the higher mortality rates on the tenth day compared with the seventh day.

The current results agree with what was indicated by (Sharma, & Yadav,2023) who explained that increasing exposure duration and spore density enhances the efficacy of entomopathogenic fungi by providing sufficient time to complete the stages of fungal infection. They also agree with(Ortiz-Urquiza,2013), who explained that the success of B. bassiana depends on the integration of the stages of adhesion, germination, penetration, and growth inside the host's body, and that any factor improving spore survival on the insect's surface contributes to increased virulence and higher mortality rates.

Table 2. Percentage mortality of termite workers when using different concentrations of the two treatment types by spraying over an exposure period of (10 days).

Treatment	Concentrations	Total	1	2	3	Number Mean	Percentage (%)
Spraying with spore suspension	$1X10^6$	30	14	15	16	**15.0 C**	50.0
Spraying with spore suspension	$1X10^7$	30	19	20	21	**20.0 B**	66.7
Spraying with spore suspension	$1X10^8$	30	23	24	25	**24.0 A**	80.0
Spraying spore suspension with gum arabic	$1X10^6$	30	17	18	19	**18.0 B**	60.0
Spraying spore suspension with gum arabic	$1X10^7$	30	22	23	24	**23.0 A**	76.7
Spraying spore suspension with gum arabic	$1X10^8$	30	26	27	28	**27.0 A**	90.0

The identical capital letters in each column mean there is no significant difference between them. LSD at P=0.05

The results of Table (3) showed that, after fourteen days of exposure, all treatments recorded the highest mean numbers of dead workers and the highest mortality rates compared with the two previous exposure periods (7 and 10 days). The mean numbers of dead workers in the treatment involving spraying with the spore suspension were 21.0, 26.0, and 27.7 workers at concentrations of (1×10^6, 1×10^7, and 1×10^8) spores/ml, respectively, corresponding to mortality rates of 70.0, 86.7, and 92.3%, whereas the treatment involving spraying with the spore suspension mixed with the aqueous Arabic gum solution recorded means of 24.0, 28.0, and 28.7 workers, with mortality rates of 80.0, 93.3, and 95.7% at the same concentrations. Significant differences ($P\leq0.05$) were observed among the means, indicating the continued effects of both concentration and treatment type in increasing fungal efficacy until the end of the exposure period. The superiority of the spore suspension mixed with the aqueous Arabic gum solution treatment also continued, particularly at the concentration of 1×10^8 spores/ml, which achieved the highest mortality rate of 95.7% compared with 92.3% for the spore suspension alone.

The continued increase in mortality rates after fourteen days is attributed to the fungus having reached an advanced stage of the infection cycle. Most spores that successfully caused infection during the initial days had completed their development inside the host, leading to the accumulation of infections and their reaching the highest levels by the end of the exposure period. This indicates that the extended time period not only increased the chance of infection occurring but also allowed the fungus to complete the disease cycle fully, which was reflected in mortality rates reaching their maximum values. The efficacy of entomopathogenic fungi gradually increases with prolonged exposure as a result of the completion of fungal colonization of the host and the continued biological activity of the fungus until death occurs (Wang,2021).

The superiority of treating the spore suspension mixed with the aqueous solution of gum arabic continued until the end of the experiment. This may be attributed to the ability of gum arabic to form a thin colloidal layer around the spores, which helps maintain the stability of the bioinoculant during the exposure period and limits spore loss over time, thereby increasing the number of effective spores capable of completing the infection cycle. Consequently, the efficacy of the treatment continued to increase until the end of the experiment compared with the spore suspension alone, consistent with the physical properties of gum arabic as a film-forming material and stabilizer of biological materials (Prasad,etal.2022).

The current results are consistent with those reported by (Ortiz-Urquiza,2021), who explained that completion of the infection cycle of the fungus B. bassiana inside the insect's body leads to a clear increase in virulence over time as a result of continued hyphal growth and the secretion of secondary toxins. (Wang,etal.2023) also indicated that the higher mortality rates in the later exposure stages reflect the fungus's success in colonizing the host's body and causing physiological disturbances that lead to death. Similarly, (Sharma, & Yadav,2023) demonstrated that combining high fungal concentrations with prolonged exposure is one of the most important factors increasing the efficiency of entomopathogenic fungi when used in biological control programs.

The current results agree with what was indicated by (Al-Jassani, & Al-Zubaidi, 2015) the gradual death of termite workers exposed to the fungus M.anisopliae may be attributed to the time required for the fungal spores to reach the bodies of the termite workers, adhere to the cuticle, penetrate the body wall through natural openings and weak areas between the segments, germinate, and produce toxins that lead to the insect's death.

Table 3. Percentage mortality of termite workers when using different concentrations of the two treatment types by spraying over an exposure period of (14 days)

Treatment	Concentrations	Total	1	2	3	Number Mean	Percentage (%)
Spraying with spore suspension	$1X10^6$	30	20	21	22	**21.0 C**	70.0
Spraying with spore suspension	$1X10^7$	30	25	26	27	**26.0 AB**	86.7
Spraying with spore suspension	$1X10^8$	30	27	28	28	**27.7 A**	92.3
Spraying spore suspension with gum arabic	$1X10^6$	30	23	24	25	**24.0 B**	80.0
Spraying spore suspension with gum arabic	$1X10^7$	30	27	28	29	**28.0 A**	93.3

Spraying spore suspension with gum arabic	$1X10^8$	30	28	29	29	**28.6 A**	95.7

The identical capital letters in each column mean there is no significant difference between them. LSD at P=0.05

Conclusions

The study results demonstrated that the fungus B. bassiana has high efficacy in controlling workers of the termite insect, with its effectiveness increasing as the spore concentration and exposure period increased. The highest mortality rate was recorded at the concentration (1\times10^8) spores/mL after fourteen days of treatment, confirming that fungal efficacy depends on both inoculum density and the time required for complete fungal infection.

The results also showed that adding an aqueous solution of gum arabic to the spore suspension improved fungal efficacy and increased mortality rates at all concentrations compared with the spore suspension alone. This indicates that gum arabic is a promising additive that may contribute to improving fungal inoculum performance and enhancing its effectiveness in biological control programs.

The results confirm the possibility of using B. bassiana, alone or mixed with an aqueous solution of gum arabic, as a promising biological alternative to chemical pesticides in controlling termites, supporting the trend toward developing safer and more environmentally friendly control methods.

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