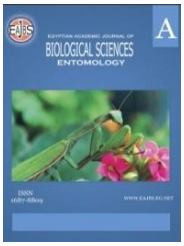
Citation: *Egypt. Acad. J. Biolog. Sci. (A. Entomology) Vol. 15(2) pp.11-17 (2022)*
DOI: 10.21608/EAJBSA.2022.239709

Egypt. Acad. J. Biolog. Sci., 15(2):11-17(2022)

Egyptian Academic Journal of Biological Sciences
A. Entomology

ISSN 1687- 8809
http://eajbsa.journals.ekb.eg/



Food Preference and Survival Rates of *Allodontermes tenax* (Isoptera: Termitidea)

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ARTICLE INFO

Article History
Received:28/4/2022
Accepted:26/5/2022
Available:28/5/2022

Keywords:
Termites, food, survival, preference, Allodontermes tenax

ABSTRACT

The main goal of this research was to determine food preference and survival rates of *Allodontermes tenax.* Traditionally, *A.tenax* has been induced to swarm during the dry season. In order to determine the best substrate for mass production, it was necessary to find a suitable food substance that enhanced the survival of the termites in the laboratory and hence can be applied in situ. The study was carried out in Trans-Nzoia at an altitude of 1,900 meters, with a latitude of 1°1'8.72"N, and a longitude of 35°0'8.3"E. The main activity in the area is crop farming and livestock husbandry. Termite workers were collected when swarming and placed in 500grams collection jars and taken to the laboratory. Some of the alates and a number of small or large soldiers and workers were preserved in 80% ethanol for identification. The experiments involved testing food preference and survival rates on maize cob husks on loam soil; maize stalk on loam soil; eucalyptus wood on loam soil; wheat straw on loam soil; pinewood on loam soil and loam soil alone as a substrate. The loam soil was put in an incinerator for 24hours to remove any organic matter present in the soil for all the treatments. The insect used in these experiments were workers of at least the third instar since earlier experiments have shown that workers below the third instar have a low survival rate under the same laboratory conditions. Two experiments were performed to determine food preference and survival rates. For each experiment, 15 rearing containers measuring 18x15x7 cm were used. After 2, 4 and 6 weeks, the samples were removed from the rearing chamber and the surviving termites were counted. The number of surviving termite workers found from each treatment was used to calculate the survival rate. The treatment with the highest survival rate was deemed the most preferred food and hence enhanced survival. The rate of survival was highest in wheat straw and loam with a grand average of 82.26% followed by maize stalk and loam with 63.82%. Apart from the control experiment, the lowest survival rates were observed in a pinewood at 47.72%. This shows that wheat straw enhanced the survival of *A. tenax* and hence the most preferred food item.

INTRODUCTION

Termite alates have historically been consumed in many parts of the world from time immemorial. Termites delicacy is well known to many people in Kenya, has high protein content (Gahukar *et al.,* 2020) and its abundance is unquestionable (Makila *et.al,*

2018). Kenya largely depends on agriculture to satisfy its food demands. In recent years there have been unforeseen and unpredictable weather changes prompting a decline in yields which results in poor harvests. There is therefore danger of chronic and sometimes acute food shortages that is likely to affect the nutritional and health status of the people. To reduce the chronic food shortages in Kenya, varieties of food sources are required with termites being one of them. They are a cheaper source of proteins as compared to fish, chicken and beef (Makila, 2018). Termites have a long history of consumption in western Kenya during both rainy and dry seasons. They are a rich source of protein and thus serve as an important diet. While a rump steak yields 322calories per 100 grams, and codfish 74 calories per 100g, termites provide 560 calories per 100g (Itakura, 2006). Termites rank among the highest in fat content (Itakura, 2006). Therefore, there is a need of making them available and en-mass for packaging to satisfy the demand of the general population. The present study was carried out to determine food preference and survival rates of *Allodontermes tenax* under laboratory conditions.

MATERIALS AND METHODS

Study Area:

The study was carried out in Trans-Nzoia (Fig. 1) at an altitude of 1,900 meters, a latitude of 1°1'8.72"N, and longitude of 35°0'8.3"E The main activity in the area is crop farming and livestock husbandry. The climate is generally warm and temperate. There is a bimodal rainfall in Kitale and averages 1097 mm annually, with precipitation even during the driest month. The average annual temperature is 18.3 °C. The area has a high variation in temperature ranging from 10.5 ºC minimum to 25.5ºC maximum within the year thus favoring the growth of agricultural crops within the area. The number of households within the study area according to the 2010 census is approximately 822,850. The land is under individual ownership and partly through cooperates such as the several forest farms spread along with the breath of the area.

Fig. 1: Map of Trans Nzoia County showing the location of the study area (Source: Adapted and modified from Microsoft Encarta 2008)**.**

Collection of Termite Workers' Samples:

Termite workers were collected from Trans–Nzoia County- Kitale during long rain periods when they were available. Colonies were marked and mapped, and 50% of the

colonies were re-sampled any time there was swarming. The selection of the sampling sites was guided by past experience and after an interview with various stakeholders in the region who are experts in identifying areas where termite alates predominate. Collection of termite workers was done during swarming. Other termite workers were collected by breaking open the termite mound away from the direction of sunlight. The collected samples were put in 500gram plastic jars and taken to the laboratory for the experimental assays. Some of the alates and a number of small or large soldiers and workers were preserved in 80% ethanol for morphological identification at the National Museums of Kenya. Approximately 1200 live individuals from each colony were collected. Collections did not discriminate between small or large workers, or soldiers. There were no interviews with the local people about the uses of termites and trapping as this has already been done in our previous work (Bagine, *et.al.*, 2014).

The experiments involved testing food preference and survival rates on 1) maize cob husks on loam soil, 2) maize stalk on loam soil, 3) eucalyptus wood on loam soil, 4) wheat straw on loam soil, 5) pine wood on loam soil and lastly 6) loam soil alone as a substrate. The loam soil was put in an incinerator for 24hours to remove any organic matter present in the soil. Termites used in this study were collected in May 2017 from termite mounds in Kitale and West Pokot-Nasukuta, Kenya. The samples were then transported to Kenya Agricultural and Livestock Research Organization (KALRO) - Kitale laboratory in open collecting jars. Termites were manually and carefully extracted. The insects used in these experiments were workers of at least the third instar since earlier experiments have shown that workers below the third stage have a low survival rate under the same laboratory conditions (Hua & Kirton2007). Two experiments were performed to determine food preference and survival rates (Haverty, 1979; Hua & Kirton, 2007). For each experiment, 15 rearing containers measuring 18x15x7 cm were used. The study involved an experimental design with three treatments (of 2-, 4- and 6-weeks duration) and 5 replications each. Since humidity is such an important factor in these insects' survival, the water/substrate proportions used in these experiments were 1 volume of water to 4 volumes of each substrate (Munizaga, 2018). A total of 150 termite workers and alates randomly selected were introduced into each container, which was kept in a rearing chamber in permanent darkness at a constant temperature of 24±2 ºC and at 80±5% relative humidity. After 2, 4 and 6 weeks, the samples were removed from the rearing chamber and the surviving termites were counted. The survival rate was estimated as a percentage of surviving workers found for each treatment. (T1, T2 and T3: 2-, 4- and 6-weeks duration, respectively) for the substrates tested.

Statistical Analysis:

Data were analyzed using ANOVA and the significance level was set at 0.05. Means±SE were separated by Fishers least significance difference (LSD) test. All statistical analyses were performed using the analysis package SAS 9.1 Copyright (c) 2002-2003 by SAS Institute Inc., Cary, NC, USA.

RESULTS

Survival Rates During Laboratory Studies:

The rate of survival was highest in wheat straw and loam with a grand average of 82.26% followed by maize stalk and loam at 63.82%. Apart from the control experiment, the lowest survival rates were observed in a pinewood at 47.72%. This shows that wheat straw enhanced the survival of *A. tenax.* From Figure 2 the rates of survival were highest during the first two weeks then started to decline from the fourth (4^{th}) week up to the sixth (6^{th}) week across all the food substances that were provided for the termite workers.

Results also showed that maize cob husks and loam soil did not significantly $P > 0.05$ affect the survival of the termite workers. Similarly, maize stalk and loam soil; pine wood and loam did not significantly affect the survival of termite workers of *A. tenax* $P > 0.05$. However, Eucalyptus wood and loam; wheat straw and loam; loam soil alone significantly affected the survival of *A. tenax* workers $P < 0.05$. The workers had the highest percentage survival rate on a wheat straw while more deaths were found on loam soil alone as shown in Figure 2.

Table 1: Survival rates of *Allodontermes tenax* mean %± SE

Treatments	Maize cob husks and loam	Maize stalk and loam	Eucalyptus wood and loam	Wheat straw and loam	Pinewood and loam	Loam soil alone
T1	70.9±9.28a	78.5±5.99a	75.9±5.09a	92.2±2.54a	48±6.56a	6.8±1.97a
T2	52.3±3.90a	70.0±12.22 a	71.3±8.97a	87.1±3.94a	56.5±8.15a	0.8±0.49b
T3	49.3±7.14a	42.9±6.79a	38.9±4.73b	67.5±6.17b	38.7±6.78a	0.0±0.00b
Average				82.26 %		

Mean values in each row with a common letter are not significantly different from each other ($P > 0.05$).

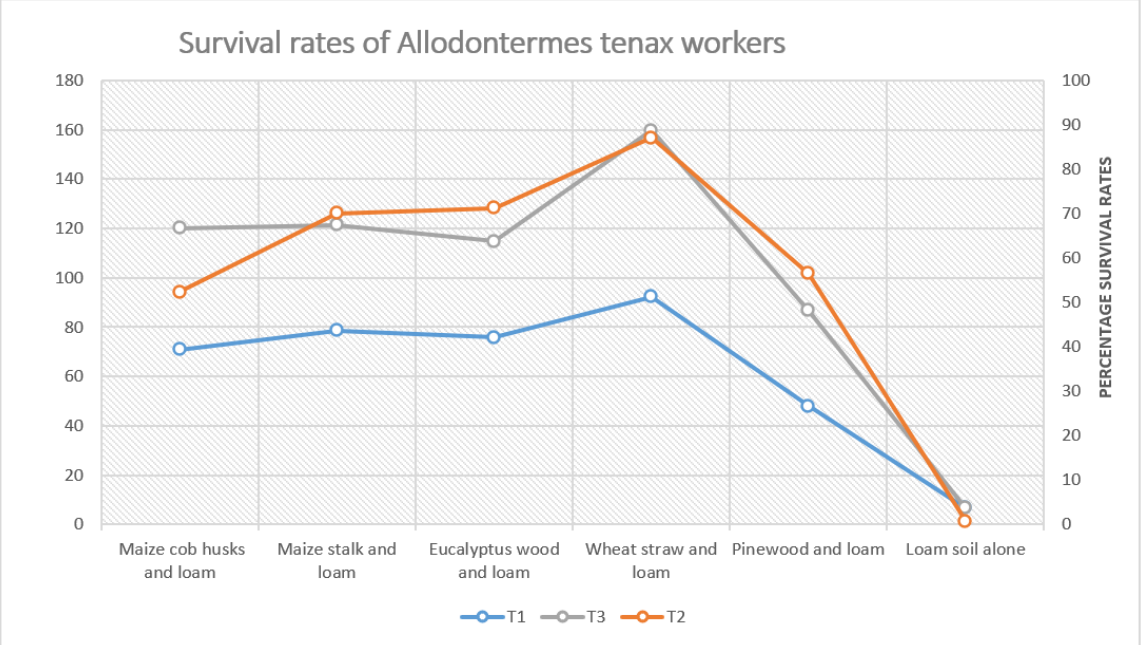

Fig. 2: Survival rates of termite workers**.**

DISCUSSION

Termites can survive up to two weeks without food, without water it takes a few days (Becker, 2012; Chouvenc, 2019). Termites in this experiment were subjected to three treatments with various cellulose-rich foods available. The treatments involved rearing the termite workers in a controlled environment for two weeks, four weeks and six weeks consecutively. The experiment agrees with previous studies such that the workers who were reared on loam soil alone, almost all survived for only two weeks mainly because of moisture content in the soil (Chouvenc, 2019). Choosing the food substances to be used in rearing depended on a prior survey of the areas where the termites occur in abundance and the type of cash crop majorly grown in the area (Wanyonyi *et al.*, 1984). Maize and wheat

were the main crops grown in the study area. From the survey, it was discovered that *A. tenax* mounds were found in abundance in Eldoret Kenya where wheat is majorly grown. This shows that distribution and abundance depend on the type of cellulose material abundant in their locality. From the experiments done in the laboratory, there was a general decline in numbers across all the food items used in rearing and treatments. Wheat straw was the most preferred food item for *A. tenax.* Termites differ in food requirement according to the species and where they are located, some species can do well on pinewood but most prefer apple, and birch and some others prefer some tropical hardwoods (Becker, 2012).

Termites also do not consume all the cellulose materials available and some of the tree species are never consumed at all like *Pinus merkusii*. It deters the feeding of subterranean termites (Arinana *et al.*, 2012). These results are in line with what was observed in *A. tenax.* Survival was lowest on the wood of pine as compared to all the other food substances provided. This is likely because the wood of pine produces some toxins that may be toxic to termites especially when the wood is not properly dried and also *P. merkusii* has a repellent effect (Becker, 2012). Even though it may have some toxins and repellant effects, the Wood of pine is the most preferred food item for *Reticulitermes* and *Coptotermes* species (Castillo *et al.*, 2013). This is due to the fact that wood composition does not remain constant, some components may be lost due to leaching and drying and making the wood still suitable for some termite species (Judd, 2018).

Food preference goes hand in hand with the survival rates of termite workers as observed from the experiment, the most preferred food caused the termite workers to survive longer than the less preferred food item. Wheat straw and maize stalk were the most preferred food items and hence caused the termite workers to survive longer as compared to the other food items used. Traditionally *A. tenax* has been harvested during the dry season for consumption by locals in the study area (Bagine *et al.*, 2014). Therefore, according to this experiment, it's the most preferred species for enhancing production.

Moisture and soil type as a substrate are also very important factors for the survival of the termites, *Coptotermes formosanus* Shiraki survived more on clay soil when moisture was low (25%) than when moisture was high (50%) since it balanced body water percentage and hence increased termite vigour (Jin *et al.*, 2020). *Allodontermes tenax* was seen to survive more on loam soil obtained in the area where the mounds were found in abundance and at a humidity of 80% and temperature of 25 ± 1^0C. This shows that each species of termite has its own preference when it comes to abiotic factors and their survival and therefore each species should be evaluated independently.

Temperature is also a decisive factor in the survival of termites. According to Haverty (1979), some termites prefer lower temperatures and higher elevations like *Heterotermes aureus* (Snyder) while others prefer low moisture and high temperatures of the lower deserts and hence the food preference will vary and will highly depend on the cellulose material abundant where they are found. *Allodontermes* was observed to be majorly found in high altitude areas like Eldoret, Kenya 2090m above sea level and Kitale, Kenya 1890m above sea level (Wanyonyi *et al.*, 1984). *Heterotermes* occur in desert and desert grassland below 1220m while *Reticulitermes* occur in grassland, oak-pinon-juniper associations and coniferous forests above 1140m (Haverty and Nutting, 1976).

CONCLUSION

Survival rates of termites are highly dependent on the type of food available in their locality, temperature amount of moisture and altitude. From this study, *A. tenax* termite species is suitable for mass production since it can be induced to swarm during the dry season. The termite workers also showed more survival rates on wheat straw and therefore the wheat straw should be used as a food item in any study on this particular

species.

Acknowledgments:

I want to acknowledge Center Director of KALRO Kitale for his immense support to use the Entomology laboratory and particularly thank Mr. Patrick Kalama for assisting in setting up the experiment.

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