IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 12 Issue 08, August 2025
ISSN (Online) 2348 – 7968 | Impact Factor – 6.72
www.ijiset.com

Survey, Identification, Seasonal Distribution and Density of Rodents in Sudan

[1]Amani Mohyeldeen Mohammed, [2]Ragaa.M.E.Elhadaa [2]Saif Eldin Mohammed Kheir.

[1]Plant Protection Directorate - Ministry of Agriculture-Khartoum

[2] Plant protection Department, College of Agricultural Studies-SUST

amani1970568@gmail.com

Abstract

The present work was aimed to identify rodents species at different four states in Sudan (Blue Nile, North Kordofan, Khartoum, and Northern State) during two years from 2019 to 2021 through the three seasons (winter, summer, and autumn).The survey was done at some various rain land and irrigated sections by different two methods (head night method and live trap method). The present study identified the flowing species of rats included the *Arvicanthus niloticus* Mibchond, *Rattus rattus* Linnaeas, *Rattus norvegicus* Berkenhout, *Mus musculus* Linnaeas, *Gerbillus campestris* Lochi and *Xerus rutilus* Cretzschmar. The results also showed the effect of the rain and soil on rat density in the rain land states. The rain and the clay soil reduced the rat density, while the sand soil did not affect rodent density. This could be used to develop, an integrated pest management based, on different species and different geographical distribution.

Keywords: rat identification, rat survey, rat density, Rattus rattus L.

1. Introduction

Rodents are one of the most important mammalian order which has a great numbers of rodent species with their effect on the environment. Directly, through their destructive feeding habits and indirectly as a vector of more than 100 bacterial and protozoa diseases in the food chains (Witmer, *et al.,* 1998). In addition they are carriers of at least (20) severely debilitating diseases to human (Meerburg, *et al*., 2009).

Rodents considered as 44% of the world's mammals and exist in every continent except Antarctica (Wolff and Sherman, 2007). There are about 2000 species of rodents known to science (Wilson and Reeder, 1993, Burgin, *et al*., 2018) and only 5-10% are agricultural pests (Stenseth, *et al*., 2003).

Rodents are involved in several types of damage, including crop and tree structural property, and cable damage. They are not only depend on man for their food and shelter but also cause infestation in agricultural fields, shops, homes, god owns and transmit infectious diseases to human and their livestock directly by biting or indirectly by vector (Witmer, *et al.,* 1998, Aplin, *et al*., 2003).

Losses by rodents lead to under-nourishment and starvation. For a long time, farmers have considered rodents as an unavoidable pest in their fields and are serious competitors with people for cereals, and occasional huge rodent population outbreaks ruin harvests (Stenseth, *et al*., 2003).

Rats and mice have a significant role in economic losses of developing countries. In 1977 Bashir, et al (personal communication) found that rats caused damage to wheat and ground nut about 15-70% and 15-30% respectively in some parts of the Gezira region.

Justification: - There is a lack in information and details in research studies about rat identification in Sudan in different states.

Objective: -The present study aims to identify of rodent species at mentioned study area in Sudan to develop an integrated pest management program for controlling mentioned species.

2. Materials and methods

2.1 Rodents population survey

2.1.1 The study sites

The present investigation was carried out in four states of Sudan to determine the rodent population and the different species. The rain rates and temperature degrees were obtained from Meteorological Authority (Khartoum).The selected states were:

1. Blue Nile State. This area (Aldamazin) is located among longitude (34.34. 21 ºE) and latitude (11.78. 54 ºN). The state considered as a rain land area and the rate of rain is in the range of (15.4 – 223.6mm) for the year (2019-2020), while it was in the range of 17.6 –193 mm) for the year (2020-2021).The temperature ranged from (16.4 – 41.4 ºC) and (14.6 – 41.5 ºC) for the two years respectively. The kind of the soil is clay. The farms contains (crops, vegetables, and fruits) and the livestock were (sheep, cow, and goat). In addition, there are forest trees, weeds, homes, stores and restaurants.

2. Northern Kordofan State. (Alobeid) area is located among longitude (30.13. 00 ºE) and latitude (13.11. 00 ºN). The state is a rain fed area and the rate of rain is in the range of (9.0 –224.4 mm) and (3.2 – 206.2 mm) while temperature is (14.1-40.7ºC) and Jan. 11.4 – May. 39.7 ºC) for the two different years respectively. The kind of soil is sand. The state consists of several kinds of different plants; ficus trees, forest trees, weeds, crops, vegetables, and fruits. In addition there are some livestock e.g. (cows, sheep, camel and goats).The state also contains homes, restaurants and stores.

3- Northern state :(Dongola) area is settled among longitude (30.47 03ºE) and latitude (19.14. 16 ºN).The state is an irrigated section and the rate of rain for the two studies years is (3.5– 7.0 mm) and (3.5 – 18.0mm) while temperature range is (9.8–44.7ºC) and (7.1–44.2 ºC). The kind of soil (sand or clay and light clay).The state farms involves date palm, crops, vegetables, fruits, and livestock (cow, sheep, camel, and goat). There are also homes, stores and restaurants in the different sites of the state.

4. Khartoum State: Khartoum area is placed between longitude (32.86 .66 ºE) and latitude (15.96. 66 ºN). The state is an irrigated area and the rate of rain and temperature is ranged between (4.9 – 56.3 mm) and (17-40.8 ºC) for year (2019-2020) while the rain and temperature is ranged between (3.5 – 46.7mm) and (13.8 – 41.7 ºC) for year (2020-2021). The kind of soil (sand or clay and light clay). The state farms consists of crops, fruits, date palm, vegetables, and some live stocks (cow, sheep, camel, and goat) and (chicken and fish). The state is crowded with homes, restaurants and stores.

2.2 Methods of survey

2.2.1 Head light method

The main survey used is the “head light” method (Suleiman, 1986), during the two years (2019-2020 and 2020-2021) through three seasons winter, summer and autumn. The head light method was applied as the longitudinal kilometer by car at the large fields in order to know the rat population density and the kind of species.

The method was applied by the observation of the rat number at the main roads of the cultivated fields which considered as an index of rat population. The average number of rat was noticed passing in front of the car, moving at about 40-50 kilometers per hour. According of Musa, (2019), density of rat in cultivated areas was determined by 2-3rat/km. Survey is mostly accomplished after sun-set. However, sometimes it was done at afternoon especially for the Nile rat (*Arvicanthus niloticus*) which is a diurnal pest.

2.2.2. The live trap method

To determine the rat species, the collection was made by using a live trap method (Weis, 1981). The live traps were used in the four different selected states ,during the two years (2019-2020 and 2020-2021) through the three seasons winter, summer and autumn .The live traps dimensions were (25 cm x 10cm x 10cm). For each state the traps were placed in different determined survey sites (farms, homes, stores and restaurants). All the traps were checked in the following day and captured rats were identified. Hassan, (1990) explained a density ranges of rats in hundred square meter (from zero to 5 considered low, over 6 to 10 rats considered as high density and over 10 rats considered as higher density). For each site

there was different number of traps, the following table explained the traps numbers that used in the survey according to their different sites:

The numbers of live traps in different locations

Type of Sites	No. of sites	No. of traps /site	Total no. of traps
Farms	5	5	25
Homes	3	5	15
Stores	3	5	15
Restaurants	3	5	15

2.3 Identification of rat species

The rats that collected by the live trap method, which mentioned above, in Aldamazin area, appeared since 2010. It has been known as a rat with strange behaviors; aggressive, stealing money, women and children dress and gold, scaring adult and children. In this study it was classified and identified by the different following characteristics according to Mohammed (2013a).

-Body weight

-Body color

-Nipples number

-Length of (head, tail, ear, legs, fingers, feces)

-Behavior

-Litters

2.3 Data analysis

The software Statistics (8) was used to analyze the data using analysis of variance (ANOVA) procedure. Least Significant Difference Test (LSD) was used for means comparison.

3. Results

3.1 Rodents population survey

3.1.1. In cultivated area

The results of rat population survey in different states of Sudan during season (2019- 2020) in cultivated areas, were shown in (Table 1). It was noticed that from the results, in winter season the highest average of rat population density was (6 rats) in Khartoum state, and it was significantly different compared to the other three states. However, the lowest average of rat population was achieved in Blue Nile State (0.2 rat) which was not significantly different from the two states (Northern state and North Kordofan State).

During summer season the highest average of rat population density was (6.2 rats) in the two states of North kordofan and Khartoum which is not significantly different with averages of rats population density in Northern state. However, the lowest number of rat population was noticed in Blue Nile state (2.0 rats).

The average number of rat population during autumn season, was high in North kordofan (5.4 rats), however, there was no significant difference between this number of density and that one in Khartoum state.

While the lowest average number of rat population was found in the two states (Blue Nile and Northern state) which were vary significantly with the average number of rat population in North Kordofan. No significant difference was noticed between the average number of rat population among the three states (Blue Nile, Northern State and Khartoum).Generally that means, the average number was nearly similar in the all mentioned states.

Table (1). P on of rodents in cultivated area in four states of Sudan during year (2019-2020)

Survey area	Rat population (NO.)		
	Winter	Summer	Autumn
Blue Nile (Aldamazin)	0.2[b]	2.0[b]	1.0[b]
North Kordofan (Alobeid)	1.0[b]	6.2[a]	5.4[a]
Northern State (Dongola)	1.6[b]	4.6[a]	2.0[b]
Khartoum State (Khartoum)	6.0[a]	6.2[a]	3.0[ab]
C.V%	50.8	29.2	77.1
SE±	0.7	0.8	1.3

Means within columns followed by the same letters are not significantly different (LSD)

Table (2) showed the results of the rat population survey in different states of Sudan during season (2020 - 2021). It was observed that from the results, in winter season the highest average number of rat population was (6.8 rats) in Khartoum state, which was significantly different compared to the other three states. No significant difference was noticed between the average number of rat population that achieved in the three states (Blue Nile, North kordofan, and Northern state) however, the lowest average number of rat population density was achieved in Blue Nile State (0.2 rat).

During the summer season the highest average number of rat population was (7.4 rats) that noticed in Khartoum state which was not differ significantly with the rat population in North Kordofan state (7.2 rats). While, the lowest average number reported of rat population was (2.2 rats) in the Blue Nile state which have no significant difference with the rat population in Northern State.

Moreover, from the above explanations, the results showed that, the two states (North kordofan and Khartoum) have the same observation of rat population which was significantly vary with that in the two other states (Blue Nile and Northern State).

In the autumn season the high average number of rat population density was noticed (4.8 rats) in the North kordofan state. While, the mid average number of rat population was registered (2.0) in the two state (Northern state and Khartoum state). But, the lowest average number of rat population density was observed (o.4 rats) in the Blue Nile state.

Table (2). Population of rat in cultivated area in four states of Sudan during year (2020- 2021)

Survey area	Rat population (NO.)		
	Winter	Summer	Autumn
Blue Nile (Aldamazin)	0.2[b]	2.2[b]	0.4[c]
North Kordofan (Alobeid)	0.8[b]	7.2[a]	4.8[a]
Northern State (Dongola)	1.6[b]	4.2[b]	2.0[b]
Khartoum State (Khartoum)	6.8[a]	7.4[a]	2.0[b]
C.V%	49.4	32.8	37.6
SE±	0.7	1.0	0.5

Means within columns followed by the same letters are not significantly different (LSD)

3.1.2. In non -cultivated areas

Figure (1) showed the results of the seasonal distribution of rodent in the non - cultivated area in the different four states (Blue Nile (Aldamazin), North Kordofan (Alobeid), Northern state (Dongola) and Khartoum state (Khartoum) in various locations (homes, stores and restaurants) during year (2019/2020). The results indicated that, generally, in non-cultivated area the population rat was high in the four mentioned states according to the suitable environment (foods, burrows, cracks, false roofs, shelter, and garbage).

The results indicated that, the higher density (15 rats) of rat at homes location, during the three seasons, was found in Aldamazin area. Similar density of rats was found in Khartoum area in summer season. The lowest density (12 rat) of rat during winter was found in the two areas North kordofan (Alobeid) and Khartoum areas. While the lowest density (10 rats) during summer was found in the North Kordofan area. In addition, the lowest density (11 rats) of rat during autumn was found in the Khartoum state.

Showed that, the density of rat at stores, was semi nil during the three seasons, in North Kordofan (Alobeid) area. But the highest density (15 rats) was found in Blue Nile (Aldamazin) area at stores location during the two season's summer and autumn. In addition, in winter season, the higher density (13 rats) was found in Khartoum state. The highest density of rat in restaurants (15 rats) was found in Blue Nile (Aldamazin) state and North Kordofan (Alobeid) state in summer seasons. Similar density of rats was also found in Blue Nile (Aldamazin) area during autumn season. While the lowest density (10 rats) was found in North Kordofan (Alobeid) in autumn season. During winter season in restaurants, the numbers of rat were nearly similar in the four mentioned states.

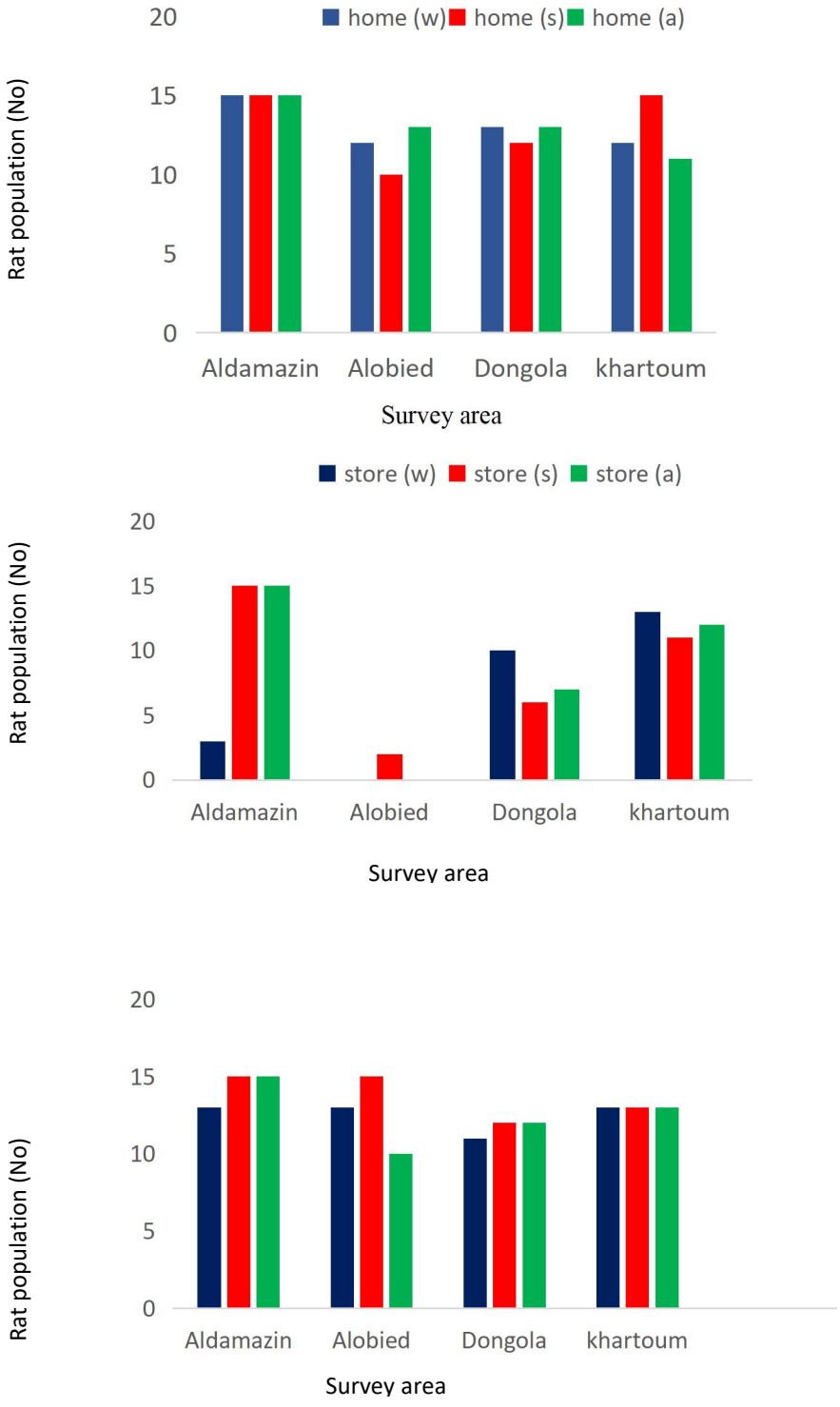

Figure (1): Population of rat in non-cultivated area in four states of Sudan during year (2019 – 2020) through 3 seasons (winter (w), (summer(s), and autumn (a))

Figure (2) showed the results of the seasonal distribution of rodent's density in non - cultivated area in the four states (Blue Nile (Aldamazin) , North Kordofan (Alobeid) , Northern state (Dongola) and Khartoum state (Khartoum) in various locations (homes, stores and restaurants) during the three seasons (winter, summer and autumn) in year 2020/2021.

The results indicated that, the highest density (14 rats) of rat at home location, was found in Khartoum state in winter season, while the lowest density (10 rats) was found in the two states (Blue Nile (Aldamazin) and north Kordofan). In summer season, the highest density (15 rats) of rat at home locations, was found in Aldamazin area. Similar density of rats (13 rats) was found in North Kordofan and Khartoum states. However, the lowest densities (9 rats) of rat during summer was found in Northern (Dongola) which was also contained the lowest number of rats (7rats) during autumn season. Khartoum state involved the higher numbers of rats more than the other states during autumn season.

At stores locations, no rats were noticed in North Kordofan (Alobeid) area, during the three seasons, however, the highest density were found in Khartoum area which involved 13,15, and 13 rats during winter, summer and autumn respectively.

The results indicated that, Aldmazin area contained the highest density (15 rats) of rats at restaurant location, during the three seasons. Similar higher density of rats was found in Northern (Dongola) area in summer and autumn seasons. The lowest density of rats were found in North Kordofan (Alobeid) during the three seasons.

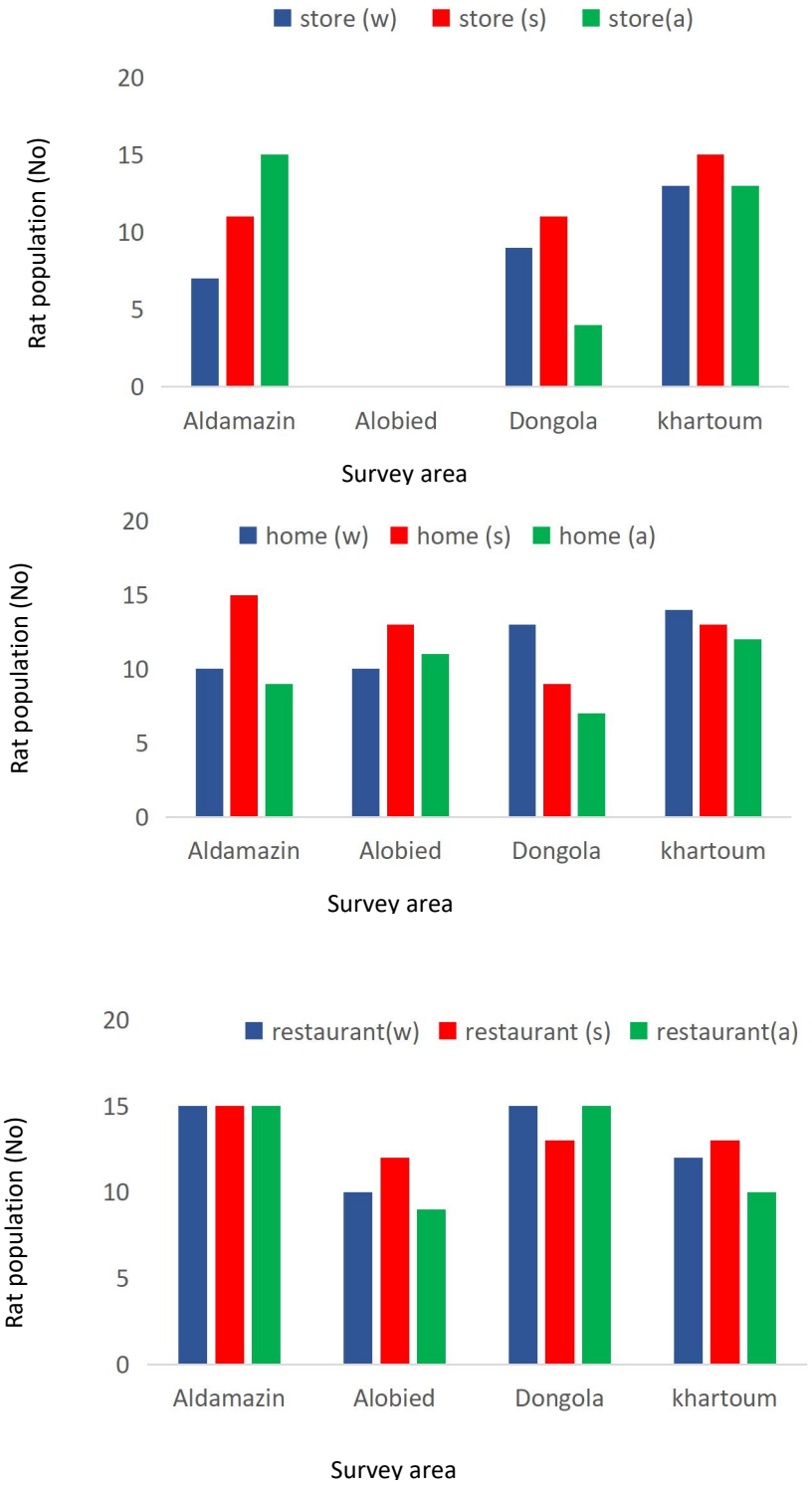

Figure (2): Population of rat in non-cultivated area in four states of Sudan during year (2020 – 2021) through 3 seasons (winter (w), (summer(s), and autumn (a)

3.2. Identification of rodent species

Table (3) showed the results of the different species of rodents according to the survey that conducted in the mentioned four states in cultivated area and non-cultivated area.
In cultivated areas the dominant species of rodents were: *Arvicanthus niloticus, Rattus rattus, Gerbillus campestris* and *Xerus rutilus,* while in non- cultivated areas the dominant ones were: *R. rattus, R. norvegicus* and *Mus musculus* at homes but in the stores and restaurants areas the species that found was *R. rattus*.

Table (3). The species of rodents in cultivated and non-cultivated areas.

States	Species of Rodents (S.N)	
	Cultivated area	**Non-cultivated area**
Blue Nile (Aldamazin)	*Arvicanthus niloticus* Mibchond	*Rattus rattus* Linnaeas *Mus musculus* Linnaeas
North Kordofan (Alobeid)	*Gerbillus campestris* Lochi *Xerus rutilus* Cretzschmar	*Rattus rattus* Linnaeas *Mus musculus* Linnaeas
Northern State (Dongola)	*Arvicanthus niloticus* Mibchond	*Rattus rattus* Linnaeas *Mus musculus* Linnaeas
Khartoum State (Khartoum)	*Arvicanthus niloticus* Mibchond *Rattus rattus* Linnaeas	*Rattus rattus* Linnaeas *Mus musculus* Linnaeas *Rattus norvegicus* Berkenhout *Arvicanthus niloticus* Mibchond

3.2.1. Identification of *Rattus rattus* (Aldamazin)

Table (4) showed the Characteristics that had been used to identify the rat *Rattus rattus.* This rat was noticed in the Blue Nile (Aldamazin) state since 2010, where the local name was bashinbo. Its behaviors were, aggressive, scaring adult and children, and stealing (money, women and children dress, and gold). Some people of Aldamazin rural area, in Alsaid village were eat this kind of rat and they don't try to use any method of control, therefore, the population was increased.

Table (4). The identification characteristics of *Rattus rattus* (Aldamazin)

Characteristics	Distribution
Weight (g)	Male ; 72-140 -162 – 179-190g Female; 60 -120 -153 -175 -180g
Length (head,+ body)	Male ;16 -16 -17 -18 -21cm ,(16 - 21) cm Female; 14 - 15 - 17- 18 -19 cm, (14 - 19) cm
Length of tail	Male ;18 -18 -19 - 20 - 23cm (18 - 23) cm Female; 16 -17 - 19 - 20 - 21cm (16 - 21) cm
Ears **Teeth** **Skull**	(2.5cm). Large, nearly nailed. (16) Teeth's (2 incisor and 6 molar in each jaw). Rectangular
Eye	Large.
Snout	Pointed
Front leg	4cm with 4 fingers
Back leg	5cm with 5 fingers
Nipples	(10) Nipples (2pair in breast and 3pair in belly).
Color	Ventral side: mixed grey and black. Dorsal side: white and grey color.
Fur	Smooth and heavy.
Feces	Pointed –shape .up to(1cm)
Sense organs	Smell-taste-hearing-touch are good
Feeding habitants	Omnivorous, mainly fruits, grains. Vegetable and insect.
Shelter Nests	Mainly wall, attics, trees…
Activities behavior	Agile, active ,can climb, swim, jump,….etc
Litters	3 –5 young
Behaviors	Aggressive, stealing money, women and children dress and gold, scaring adult and children.

4. Discussion

Rodents are the largest group of mammals, harmful animals in agricultural environments that cause great damage to field and orchard crops. Moreover, they can contaminate stored foods and crops and spread diseases salmonella, hanta virus and wails disease as well as transmit bacteria and virus from their fur onto any surface that they come into contact.

The present study was conducted in four states in Sudan with contrasting agro-ecosystems during two years through three seasons. The four states were, (Blue Nile, North Kordofan, Northern and Khartoum states).

The survey results indicated that different kinds of rodents are available in almost every seasons of the two years (2019 - 2020) and (2020-2021) in the four mentioned states. Traps are always used in surveying and monitoring rodent's population. Many traps and trapping methods have been developed and used for mammals (Proulx, 1999).The results indicated that trapping methods which has been used in the present study, could be a successful methods of rodent's identification, and were more success especially the live traps. The following advantages of traps were stated by Bennett *et al.,* (1997): they are safe, provide quick results, and collect various kinds of live rats. According to the experience encountered during this study the traps losses considered a practical problem as survey method.

The population densities was noticed to be high due to the annual continuous availability of food in these areas, where the ecosystem is a combination of cultivated and non – cultivated area. However, in non-cultivated area the availability of rodent's appearance was more than the cultivated areas. Meerburg *et al*., (2004) reported that, the temporal variations of rodents in human environment is smaller than the variation in the field environment. These kind of commensal rodent species are living in close association with human where food is a permanently available.

In Aldamazin area, which rat appear since 2010 aggressive, stealing money, women and children dress and gold, scaring adult and children, was classified and identified by the different following characteristics was roof rat (*Rattus rattus*). Corbet and Southern, (1977) reported that for the roof rat *(Rattus rattus*) if environmental conditions allow it, successful breeding may occur all year.

This study provided some information about the available rodent species in different states in Sudan. The results showed that generally, there are (6) rodents species infesting the four mentioned states in Sudan. The dominant species at farm was the Nile rat *Arvicanthus niloticus*. The distribution of the Nile rat in Sudan has been reported by many workers. It has been reported by Owen (1953) to be abundant in central and southern Sudan, Blue Nile province, Khartoum and Northern Province. Also it was reported in Khartoum province by Happold (1967) and Mohammed (2013 b).

The other three species collected in this study were the Roof rat *Rattus rattus* which was the dominant species in the residential area, the Norway rat *Rattus norvegicus* which was present in homes, and the house mouse *Mus musculus* that was trapped in the residential area. These three species are known to be the most important commensal rodent species. According to Bennett *et al*., (1997) they are called commensal because they have been sharing people's food and shelter for many years. The genus *Rattus* has been reported by Owen, (1953) to be widely spread in Sudan. In addition, Taylor, (1984) stated that, the roof rat *R. rattus* is almost universally present in towns, villages and even remote farms throughout the African continent. It is a very serious pest and disease reservoir in commercial and domestic premises. He also mentioned that, the Norway rat tends to occur in ports and highlands towns in tropical Africa, it is also more widely distributed in North Africa; it is too a troublesome rat.

The results in this study confirmed the presence of Nile rat in Khartoum state inside the farms stores and the village that closed to the farms. Kassab *et al*., (1963) explained that, this kind of rat considered to be as a pest of stored products especially in villages and places near fields. In addition, Kamil and Ghobrial ,(1972) stated that, the Nile rat is an agricultural pest in different parts of Sudan but it has been reported as commensal in some areas in the Gezira scheme, especially when the villages are close to the farms.

In North Kordofan (Alobeid) area the density of rat at stores, was semi nil during the three seasons, because the cats there had ate or scared them.

According to the results of this study, the two species of rodents *Gerbillus campestris* and *Xerus rutilus* were just found in North Kordofan. The genus *Xerus* was found to be eaten by peoples in these area.

During the two years of study, it was noticed that, the highest density of rodents has been in Khartoum state in cultivated and non-cultivated areas, and that is due to the different changes of the environment and the expansion of the agricultural production and of the poultry farms and more restaurants. In addition, to the suitable environment (dirt) that provides shelter and food for the rats. According to El-Sherbiny, (1987), the changes in the agro-ecosystem, have had a great effect on the distribution and abundance of field rodent population. Moreover, Desoky, (2007) and Abdel-Gawad, (2010), mentioned that, the increase of the cover plant in different areas have been a great effect on the distribution of rodent species.

In the irrigated areas (Khartoum and Northern state), the results during started that the density of rat was more than that in the rain land areas (Blue Nile and North kordofan). This is an agreement with Smith, (1935); and Knape and de Valpine (2011) who reported that, local climatic factors, such as temperature and rainfall, are generally considered important extrinsic or density-independent limiting factors.

According to this research, the density of rat in rain area subjectively in the sand soil (North kordofan), was higher than that in the clay soil (Blue Nile). Massawe *et al*., (2008), Meliyo, *et al.,* (2015), and Mlyashimbi, *et al*., (2019), reported that soil types have been shown to influence rodent abundance with sandy loam soils sustaining higher rodent abundance compared to clay soils.

The data obtained in this study about identification and density of rodent species in Sudan, can be used in the future as effective strategy plan for implementation of rodent management programs.

5. Conclusions

- In cultivated areas, during the two years (2019-2020 and 2020-2021), the rat population, was higher in Khartoum state due to the high diversity of mixing agriculture (vegetables, crops, animals, fish, poultry...). In Blue Nile (Aldamazin) area the density of rat was low, because of the natural enemies that found in the area, in addition, people there also can eat the rat especially the Nile rat. The dominant species of rat in the different three states was the Nile rat, except in North kordofan there were gerbils and squirrels.
- In non-cultivated area during the two years the population rat was high in the four states according to the suitable environment (foods, burrows, cracks, false roofs, shelter, garbage…).The dominant rat in the four states, was the black rat (*R.rattus*).

References

Abdel-Gawad K. H., (2010). Rodent species composition in the present compared with past, the 5th Scientific Conferences for Agric. Assiut Univ. Oct. 16-17, 2010 (159-167).

Aldeeb, H.E. (1990). Rodents and method control .Machine Control by traps. Chapter (4). p 96. Egypt. In Arabic.

Aplin, K. P., Brown, P. R., Jacob, J., Krebs, C. J. and Singleton, G.R., (2003). Field methods for rodent studies in Russia and the Indo-Pacific. Melbourne: BPA Prinnt Group, Australian Centre for Agricultural Research, 223 p.

Bashir, E. A, H. Abbas, and E. L. Bashir**.** (1977). Rat outbreak and Control in the Sudan with reference to the Gezira scheme (personal communication).

Bennett, G, W., Owens, J.M., and Corrigan, R.M. (1997). Truman, Scientific Guide to Pest Control Operation.5th .Edition.

Burgin, C.; Colella, J.; Kahn, P.; Upham, N. (2018).How many species of mammals are there? *J. Mammal.* 99, 1–14.

Corbet, G, and H. Southern., (1977). The hand book of British mammals Oxford: octavo agricultural rodent pests. *Frontiers in Ecology and the Environment*, vol. 1, no. 7, pp. 367-375.

Desoky, A. S. S. (2007). Management strategies for rodents within different ecosystems. M. Sc. Thesis, Fac. Agric. Assiut Univ. 124.

El-Sherbiny, A. H. (1987). Cyclic fluctuations in rodent populations: Review of current researches. Egypt. *J. Wildl. and Nat. Resources,* 9. pp.1 7.5. 3

Happold, D. C. (1967). The mammals of Jebel Mara. *Journal of Zoology* London, 149, 126-136.

Kamil, A. S. and Ghobrial, L.I. (1972). Occurrence, distribution, habitat of the Nile rat in Sudan. Msc. Thesis Univ. of Khartoum, Sudan.

Kassab, A., Badran, A.A., and Kamel, A.H. (1963). Warfarin bait in the control of the field rat *Arvicanthis niloticus*. Mibochond in Egyptian shonas. UAR Min. of Agric., Plant Protection Dept., Cairo.

Knape, J., and P. de Valpine. (2011). Effects of weather and climate on the dynamics of animal population time series. Proceedings of the Royal Society of London, B: Biological Sciences 278: 985 – 992.

Massawe A.W., Rwamugira W., Leirs, H. *et al*., (2008): Soil type limits population abundance of rodents in crop fields: case study of the multimammate rat Mastomys natalensis Smith, 1834 in Tanzania. Integr. Zool. 3: 27–30.

Meerburg, B. G., Bonde,M., Brown, F. W. A *et. al.,* (2004). Twards sustainable management of rodents in organic animal husbandry. *Netherlands J. of Animal Science* 52, (2).

Meerburg, G.M., singleton, G.R. and kijkstra, A. (2009). Rodent borne diseases and their risks for public health. *Critical Reviews in Microbiology*, vol. 35, pp. 221-270.

Meliyo J., Brabers L., Massawe B. *et al*., (2015): The effect of soil physical properties and soil microclimate on rodent burrows' abundance and their characteristics in Western Usambara Mountains, Tanzania. *J. Agric. Ecol. Res. Int*. 2: 105–119.

Mlyashimbi E.C.M., Vanden Broecke B., Mariën J. *et al*., (2019). Influences of soil types on the population dynamics and survival of multimammate rat (*Mastomys natalensis*, S.) in semi-arid areas in Tanzania. *Crop Prot*. 124: 104829.

Mohammed, A. M. (2013a). Distribution, Species Composition and Management of Rodents in Khartoum States. M.Sc. Thesis .Univ. of Sudan Academy of Sciences.

Mohammed, A. M. (2013b). Distribution, Species Composition and Management of Rodents in Khartoum States. M.Sc. Thesis .Univ. of Sudan Academy of Sciences.

Musa, M. F. (2019) (Personal communication). Rat survey, Sudan states. Evaluation density of Rats in cultivated areas. Plant Protection Directorate (PPD), Report (in Arabic)

Owen, J. S. (1953). Afield Key, the genera of Sudan rodents, Notes and Record.

Proulx, G. (1999). Mammal Trapping; Alpha Wildlife Research and Management: Sherwood Park, AB, Canada.

Smith, H. S. (1935). The role of biotic factors in the determination of population densities . *Journal of Economic Entomology* 28: 873 – 898.

Stenseth, N.C., Leirs, H., Skonhoft, A., Davis, S.A., Pech, R.P., Andreassen, H.P., Singleton, G.R., Lima, M., Machangu, R.M., Makundi, R.H., Zhang, Z., Brown, P.B., SHI, D.Y. and Wan, X., (2003). Mice, rats, and people: the bio-economics of

agricultural rodent pests. Frontiers in Ecology and the Environment, vol. 1, no. 7, pp. 367-375.

Suleiman, S. A. (1986). (Personal communication). Rat Survey, Kordofan and Darfur Province .Plant Protection Directorate (PPD), report 17pp. (in Arabic)

Taylor, K. D. (1984**)**. Vertebrates Pest Problems in Africa. In The proceedings of a Conf. on The organization and Practice of Vertebrate Pests Control 30Aug. – 3 Sept., 1982, Elvetham, Hamshire, England. ICI Plant Prot. Div., Fernhurst, Haselemere, Surry, England.

Weis, N. (`1981). The Rodent pests and their control pages, 1-68. German Agency of Technical Cooperation. (GTZ). (In Arabic).

Wilson, D. E. and Reeder, D. M. (1993). Mammal species of the world: a taxonomic and geographic reference. Washington: Smithsonian Inst.

Witmer, G. Campbell E.W, and Boyd, F. (1998). Rat management for endangered species protection in the U.S. Virgin Islands. Proceedings of the Vertebrate Pest Conference 18:281-286.

Wolff, J.O. and Sherman, P.W., (2007). Rodent societies as a model system. In: J. Wolff and P. Sherman, eds. *Rodent societies*: an ecological and evolutionary perspective. Chicago: The University of Chicago Press, pp. 3-7.