World Journal of Agricultural Research, 2013, Vol. 1, No. 5, 85-89
Available online at http://pubs.sciepub.com/wjar/1/5/3

DOI:10.12691/wjar-1-5-3

Studies on Population Dynamics of Senegalese Grasshopper (*Oedaleus senegalensis*) in Kordofan of Sudan

Abdelmanan E. H. Elamin[1], Abdalla M. Abdalla[1], Ahmed M. El Naim[2,*]

[1]Department of Crop Protection, Faculty of Natural Resources and Environmental Studies, University of Kordofan, Sudan
[2]Department of Crop Sciences, Faculty of Natural Resources and Environmental Studies, University of Kordofan, Sudan
*Corresponding author: naim17amn@yahoo.com

Received June 25, 2013; Revised September 09, 2013; Accepted September 12, 2013

Abstract The Senegalese grasshopper (*Oedaleus senegalensis*) is a serious pest affecting cereal crops and grassy pastures in western Sudan. Intensive and extensive field's surveys were conducted over a three-year period targeting *O. senegalensis* to study its ratio among other grasshopper species, in addition to its density and population structure/dynamics. Observations made twice a week, between April and November for three years (2006-2008) in two sites in Kordofan. Light traps installed in three selected areas to study nocturnal activity and migration every night from April to November for two seasons (2007/2008). The density assessed by visual counts of the nymph instars in 100 m² and adults in 1,000 m². The obtained data were analyzed using descriptive statistics. Results revealed that the Senegalese grasshopper is dominant over other grasshopper species and that the adults and nymphal instars appeared in two morphs: green and brown, according to prevailing environmental conditions. Mean population density was 1037 adult/ha and 3464 adult/ha in Kuik and Gellabiya sites, respectively; for nymphal instars, 2145 nymph/ha and 5500 nymph/ha, in Kuik and Gellabiya sites respectively.

Keywords: *population dynamics, Oedaleus senegalensis, Senegalese Grasshopper, cereal crop, light trap*

Cite This Article: Abdelmanan E. H. Elamin, Abdalla M. Abdalla, and Ahmed M. El Naim, "Studies on Population Dynamics of Senegalese Grasshopper (*Oedaleus senegalensis*) in Kordofan of Sudan." *World Journal of Agricultural Research* 1, no. 5 (2013): 85-89. doi: 10.12691/wjar-1-5-3.

1. Introduction

The grasshopper is considered a primary agricultural pest, causing serious damage to crops and pastures every season in Sahelian countries. This is in contrast to locusts, which threaten crops only during upsurge conditions. Grasshoppers cause severe damage when large numbers appear [1,2,3]. Among the relatively few local species in the Sahel-Saharan zone (latitude 10º N and 18º N), the Senegalese grasshopper, *Oedaleus senegalensis* (Orthoptera: Acrididae), is considered to be the most important pest species, due to its economic costs [22] *O. senegalensis* has a certain importance because of the damage that it causes to consumer crops (millet, sorghum), mainly to the seedlings and ears at the milky or unripe stages [4].

Both nymphs and adults can be responsible for causing damage to crops early in the rainy season. In the late 1970s, the Senegalese grasshopper caused serious damage to *Pennisetum* spp. (millet) and to pastures in Mali [20,21]. The pest also was reported in different countries of Africa and Asia, affecting various food crops and pastures. In the Sudan, Khalil [5] recorded this grasshopper as one of the serious pests of cereal crops in the seedling and milky stages. High numbers of *O. senegalensis* observed in different locations in Northern Kordofan State. Many authors, including [2,3,6,7,8] believed that this insect undergoes egg diapauses through the dry season in the Sahel. With the arrival of the first rains, the first nymph instar emerge in high numbers and quickly produce three generations.

This species is also reported within the complex of other locust species in eastern, central, and western Sudan [5]. Recent studies have shown that Senegalese grasshoppers, like many acridian species in West African, can fly very long distances, carried by the winds at night, as documented by [3,4,9]. These movements represent a form of swarms [10]. Reference [11] recorded the important Sahelian pest species *O. senegalensis* as the most common grasshopper in the stork chick diet. Axelsen et al. [12] present a simulation study of the role of birds and egg pod predators in the population dynamics of the Senegalese grasshopper. The current study is designed to assess the population density and structure of *O. senegalensis* in support of future intervention aimed at controlling, or reducing the impact of, the pest.

2. Materials and Methods

Present study was carried out in Kordofan region. The region lies between latitude 09º 50´–16º 40´ N and longitude 27º–32º. The fieldwork conducted in two sites

during the cropping seasons of 2006/2007, 2007/2008, and 2008/2009. The sites were in Gellabiya, Northern Kordofan State, 13º 09´ N: 30º 07´ E, west El Obeid; and Kuik, in Southern Kordofan State, at 11º 20´ N: 29º 42´ E, north Kadugli. The classical acridology technique used (counting nymphs/m² and adults/1,000 m² with the naked eye). The two sites sampled twice a week throughout the rainy season. In each site, estimations of population density per hectare and population structure of the nymphs and the adults of *O. senegalensis* expressed in percentages. The adult is an average-sized, green, or brown insect that easily identified by the presence of an "x" shape on the top of its pronotum. The glossy hind wings are yellowish in color (darkening with age), with a dark crescent-shaped band at the midpoint and a white stripe across the eye. Nymphs of this species can be identified by the distinctive X-mark on the top of the pronotum, and the presence of laterally alternating green and brown spots along the abdominal segments, forming a continuous colored stripe.

2.1. Population Density of Grasshoppers

The adults and nymphs were sampled from the favored environment (millet fields, natural vegetation, and bare ground, grazing land). Since it known from previous studies that count, vary considerably according to the time of the day, counts always started at 08.00 hours. The population densities per hectare of the nymphs and the adults of *O. senegalensis* (*OSE*) were calculated.

2.2. Counting of Nymphs

Counting of the nymphs of all grasshopper species in one square meter was carried out when grass cover height was less than 20cm [7]. In each visit to the site, all grasshopper nymphs in and jumping out of this square meter at every five-meter interval counted and recorded. The procedure was repeated 100 times to obtain the number of all nymphs in 100 m², and then density per hectare was calculated using the following equation:

$$X = \frac{Y}{100} \times 10000$$

Whereas:

X = Density of all nymphs species per hectare.

Y = Total number of all nymph species counted in m² repeated 100 times.

2.3. Sampling of Nymph Instars

Sampling consisted of collecting a part of the population of *OSE* to analyze its structure. A sweepnet (with a 40 cm diameter and 60 cm hand stick) was used for collecting the nymphs from natural vegetation and field crop. They were then put in small cloth bags. The nymphs of all grasshopper species in the site were swept by walking through the vegetation. One hundred strokes were used for each counting, with a single stroke taken every five meters in different direction in the site. Nymphs of *OSE* with an x mark on the pronotum were determined and then separated.

The Senegalese grasshopper (*O. senegalensis*) nymphs' instars population density per hectare was calculated using the following equation:

$$X_O = \frac{Y_O}{Y_S} \times X$$

Whereas:

X_O = Density of *Oedaleus senegalensis* nymphs per hectare.

Y_O = Number of *Oedaleus senegalensis* nymphs swept in 100 m².

Y_S = number of nymphs of all species swept or sampled in 100 m².

X = Density of all species nymphs per hectare.

2.4. Counting of Adults

Counting of the adult *O. senegalensis* was done to follow the population density. The work was done by day in the same site where nymphs were counted in the mornings between 08.00 and 11.00 hours, when the grasshoppers were normally active and the surveyor could more easily do the counting. The transaction was carried out by walking along 100 meters (taking normal paces) from one end of the site, across wind or upwind; all the adults of grasshopper species that flew out half a meter on each side were recorded on the survey sheet. The grasshoppers that flew into the square meter were not counted, so as to avoid double counting [7]. Thus, a number of grass hoppers in a hectare was calculated using following equation:

$$A = \frac{B}{1000} \times 10000$$

Whereas:

A = Density of the Grasshoppers adults of all species per hectare.

B = Total number of all species counted in 1,000 m².

The collected *O. senegalensis* adults then sorted into green and brown females and males for further study.

2.5. Sampling of Adults

The inward 1,000-square-meter transaction was used to assess the structure of the adult population, which was based on the hardness of the tegument and ovary development. A sweep net (with a 40-cm diameter and 60-cm hand stick) used to collect the adults of all grasshopper species in the site. Researchers walked through the vegetation swinging the net from side to side, using a regular motion every five meters. This was repeated twenty-five times to collect part of the population. It is possible that two or three individuals were doing the same parallel foot transect. The adults of *O. senegalensis* were collected and identified. Mature ones were studied further by dissection and their ovaries examined. Dissection results were recorded on a dissection form. The density of the adult *O. senegalensis* was calculated using the following equation:

$$A_O = \frac{B_O}{B_S} \times A$$

Whereas:

A_O = Density of Oedaleus senegalensis adults per hectare.

B_O = Number of Oedaleus senegalensis adults swept in 1,000 m².

B_S = Total number of all species swept in 1,000 m².

A = Density of all species adults per hectare.

At each site, the mean population densities of the nymphs and the adults of *O. senegalensis* in the three seasons were compared. Correlation between means was studied.

2.6. Methodology for Calculating Percentage of Senegalese Grasshoppers

During the survey, other species in the study area were recorded. Adult grasshoppers collected using a sweep net were identified in the field soon after collection and immediately put in small cloth bag or bottle with holes. Those that could not be readily identified were examined further at the laboratory and identified by comparing them with the identification keys of Popov (1989). Some specimens were identified by Luong-Skovmads of CIRAD; France (personal communication). *O. senegalensis* adults were separated and the percentage calculated.

2.7. Light Traps

In season 2007/2008, a light trap was set up at Gellabiya site in the beginning of June. In season 2008/2009, the light trap was set up in the middle of May. An electric 100-watt lamp was used and suspended about 50 cm above a metal basin. At this site, the source of electric current was a solar-power unit. In El Obeid, a light trap was set up on the first of June in season 2007–2008, and in mid-May in season 2008–2009. The trap shape was the same as that used in the Gellabiya site. The source of electric current was the general electricity station of El Obeid city. At Kuik site, for both the 2007–2008 and 2008–2009 seasons, the trap was set up in April. A kerosene lamp (Petromax) was used and suspended about 50 cm above the metal basin.

2.8 Collection of *Oedaleus Senegalensis* at Light Traps

Light traps were used during seasons 2007–2008 and 2008–2009 as field monitors for observing the migration of the adults of this species, according to the path of movement in the intertropical convergence zone. A simple permanent trap was made of metal. It consisted of a basin (1 m × 1m × 30 cm). Its height was about one meter from the ground; half of the basin was filled with water containing a small amount of soap. A white metal board set across the metal basin concentrated the light to attract the adults. The trap was placed in an open ground away from trees and buildings. The lamp was turned on each day at 1800 hours and kept on for four to five hours to attract nocturnal grasshopper species. Adults of all species hit the metal and fell into the basin. The following morning, they were removed from the water and *OSE* adults were sorted and placed in cloth bags for further study. The trap was operated every day between May and November each season, the only exceptions being those days when there was rain and/or shortages of electricity. Data were recorded in special form. Three light traps were set up at the sites of Gellabiya, El Obeid city, and Kuik.

2.9. Statistical Analysis

Data were analyzed with the Excel statistical package, means and standard deviation were calculated. Descriptive statistics were used for statistical significance.

3. Results

3.1. Population Density of Adult and Nymphal Instars

The Senegalese grasshopper is more present than any other grasshopper species, its percentage over the three seasons (2006/2007, 2007/2008, and 2008/2009) reaching 30 percent, 17 percent, and 46 percent at Kuik site; and 11 percent, 52 percent, and 16 percent at Gelabiya site. Table 1 and Table 2 give the population density of the adults and the nymphal instars. At Kuik site, in season 2007/2008, the population density mean lower level was 722 adults per hectare and the upper was 1,388 adults per hectare, with a mean of 1,037 adults. At Gelabiaya site, the population density mean lower level was 2,036 adults per hectare and the upper was 4,842 adults per hectare, with a mean of 3,474 adults, significantly ($P < 0.05$) higher than at the Kuik site.

For nymphal instars at Kuik in season 2007–2008, the population density mean lower level was 1,007 nymph instars per hectare and the upper level was 3,273 nymph instars per hectare, with a mean of 2,145 nymph; at Gelabiya, the lower-level density was 3,453 nymph instars per hectare and the upper level was 7,547 nymph instars per hectare, with a mean of 5,500 nymph/ha in season 2007–2008, significantly ($P < 0.05$) higher than that at Kuik site. The population density for nymphs in season 2008–2009 was significantly ($P < 0.05$) higher than that recorded in seasons 2006–2007 and 2007–2008.

Table 1. Population Density per Hectare, *Oedaleus senegalensis* Adults at Kuik and Gellabiya Sites, Seasons 2006–2007, 2007–2008, and 2008–2009

	Kuik			Gellabiya		
	2006/07	2007/08	2008/09	2006/07	2007/08	2008/09
Lower level	443	722	154	644	2,086	408
Upper level	883	1,388	569	1,033	4,842	919
Confidence 95%	454	724	279	812	2,867	531
Mean± Sd	663 ± 220	1,037 ± 351*	433 ± 136	839 ± 195	3,464± 1,378**	663 ± 255

**Significant at 0.01 probability. *Significant at 0.05 probability.

Table 2. Population Density per Hectare, Oedaleus senegalensis Nymphal Instars at Kuik and Gellabiya Sites, Seasons 2006–2007, 2007–2008, and 2008–2009

	Kuik			Gellabiya		
	2006/07	2007/08	2008/09	2006/07	2007/08	2008/09
Lower level	319	1007	23	697	3453	1140
Upper level	2382	3283	3745	1985	7547	2338
Confidence 95%	2125	2348	2501	1339	4257	1246
Mean± Sd	1351 ±1032	2145 ±1138	2524 ±122*	1341 ± 644[a]	5500 ±2047*	1739 ±599[a]

**Significant at 0.01 probability. *Significant at 0.05 probability.

3.2. Population Structure

The population structure percentage average of Oedaleus senegalensis nymaphal instars was 12 percent, 18 percent, 18 percent, 20 percent, and 32 percent for the first, second, third, fourth, and fifth nymphs respectively in three seasons of study at the Gelabiya site. In the three seasons of study at the Kuik site, the averages were 14 percent, 12 percent, 22 percent, 34 percent, and 16 percent for the first, second, third, fourth, and fifth nymph instars, respectively. The mean population structure of the adults female in pre-vitellogensis stage (PV) was 19 percent and 26 percent at Gellabiya and Kuik sites, respectively; for males with hard cuticle (mature) of the total population stages at Gellabiya and Kuik sites, it was 16 percent and 23 percent respectively.

3.3. Senegalese Grasshoppers Caught in Light Traps

Table 3 gives the number of *O. senegalensis* caught in a month during the study period and shows green and brown morphs for this pest at Gelabiya, El Obeid, and Kuik light traps during season 2007/2008 and season 2008/2009. In season 2007/2008, 300 females were removed from light-trap catches and dissected. Two hundred eighty were found in pre-vitellogensis, and eight were found with spume. One hundred males were inspected and were found with hard cuticle.

Table 3. Numbers and Color of Oedaleus senegalensis Adults Caught in a Month at Gellabiya, El Obeid, and Kuik Light Traps, Seasons 2007–2008 and 2008–2009

Site	Month	2007/08		2008/09	
		Green	Brown	Green	Brown
Gellabiya	May	0	0	0	0
	June	0	6	0	32
	July	161	106	72	24
	August	91	060	42	7
	September	101	513	16	048
	October	129	850	0	464
	November	0	0	0	2
El Obeid	May	0	0	0	0
	June	0	15	3	30
	July	55	39	21	56
	August	49	12	33	16
	September	266	973	12	49
	October	135	1,702	11	439
	November	0	3	0	49
Kuik	May	7	89	0	86
	June	63	92	123	108
	July	68	35	16	6
	August	0	0	0	0
	September	5	11	0	0
	October	31	438	18	193
	November	0	500	0	113

4. Discussion

The ever-increasing need for food security in the Sudan and elsewhere in sub-Saharan countries has led to an interest in studying pests that hamper the production of staple food crops such as millet and sorghum. In the Sudan, *O. senegalensis* often reaches the status of a serious pest of cereal crops, especially in the states of Kordofan, Darfur, and Kassala. Field survey collections, coupled with light-trap collections in the present study, showed that both adults and nymphs are found in two morphs, green and brown. The results obtained by surveys of grasshopper species in the study area reveal that many species in the study sites share the same habitat. In the 2007–2008 research season the relative density of *O. sengalensis* reached 46 percent to 52 percent of all grasshopper species in the study area. It is clear that the Senegalese grasshopper infestation occurs every year and its outbreak and density depends very much on rainfall distribution in the area.

The nymph population increased after the first rainfall and the hatching of eggs. The first nymph instars develop in the south of Kordofan in April and/or in May and June, while in the north of the region, nymphal instars development happens twice: the first is in late June or early in July, and the second is in late August or early September, depending on the rainfall quantity and when it begins. This is in line with the findings of [13,14,15] a who noted that hatching is influenced by the amount of rainfall at the beginning of the season.

In the current study, a wide dispersion of the adults was noticed every year at the beginning of the rainy season, with variation in density. The individuals are scattered and populations are smaller and less obvious than at the end of the rainy season; these findings match with earlier research [1,16,17,18].

The results showed a population density mean per hectare (Table 1). The mean values are lower than that documented by [16], who reported a population density of 12,000 adults per hectare when a wire ring of one-meter diameter was used. It could be argued that the density and dynamic of the Senegalese grasshopper depends very much on ecological factors. A variation in the density from year to year and from place to place is to be expected. The population's age structure has been given much attention in the present study, and each of the five nymphal instars and adults is expressed as a percentage. The mean population density of the adult female in pre-vitellogensis stage (PV) was 19 percent and 26 percent at Gellabiya and Kuik sites, respectively. It is probable that the migration happened in the pre-vitellogensis stage for

the females and males with hard cuticle, and this finding agrees with those of [19].

The migration of *O. senegalensis* was studied carefully by the use of light traps in the research area. Considerable numbers of both females and males were collected at night and the arrival of individuals of *O. senegalensis* at light traps was recorded between 18.00 and 21.00 hours. The light trap, as a sampling tool, has been used widely in West Africa. The samples it collects are an indicator of migratory movement. It measures flux density of certain individuals passing over and around the trap [19]. In this study the movement or displacement of adults was observed from southern parts of the region to the north, when the rainy season begins in April or in May, following the advancing inter- tropical convergence zone (ITCZ). Evidence at the Kuik site was first collected from the traps in early May, after rainfall in the area. At the Gellabiya and El Obeid sites, the main collection was in June and July.

In all three sites, high numbers of *O. senegalensis* were caught in the months of September and October. The southerly wind in the breeding area helps to displace *O. senegalensis* further to the north. Adult males at the hard cuticle stage and adult females in the pre-vitellogenesis stage (immature, being about seven days old), were attracted in great numbers to the light traps, especially in October. In this study, as regards females, it is clear that flight declines as ovarian development advances, and gravid females are not found in light traps, which is consistent with the findings of [1,9,19]. Very few females with spume (laid) were caught in the traps, even though the majority of catches is in pre-vitellogensis, which conforms with results obtained by Popov (1988), who argued that the presence in light-trap catches of previously laid females resumed between oviposion and decline of flight activity at the time of reproduction, shortly before oviposition, may well be a general phenomenon in the Acridoidea.

5. Conclusions

Based on these results, it can be argued that the density and dynamic of the Senegalese grasshopper depends on ecological factors. The Senegalese grasshopper is dominant over other grasshopper species in rain-fed areas of Kordofan, that continuously exit through the three seasons of study in a high density. Therefore, efforts should be directed to the field management by launching of early survey and monitoring activities to prevent large-scale outbreaks.

Acknowledgement

Authors are highly thankful to Professor M. Lecoq and Professor M.H. Luong, skovman of CIRAD, France for providing important assistance and guidelines for the present study.

References

[1] Cheke, R.A., Fishpool, L.C.D. and Forrest, G.A. *"Oedaleus senegalensis* (Krauss) (Orthoptera: Acrididae. Oedipodinae). An Account of the 1977 Outbreak in West Africa and Notes on Eclosion under Laboratory Conditions". *Acrida*, 1980, 9: 107-132.

[2] Rowly, J., and Bennett, O., *Grasshoppers and Locusts*: *The Plague of the Sahel*. London: The Panos Institute, 1993.

[3] Diop, T., Inventaire commente de la bibliographie sur le criquet Sénégalais, *Oedaleus senegalensis* (Krauss, 1877). *Insect Sci. Applic*, 1997, 17(3/4): 277-291.

[4] Maiga, B., *Notes on the Acridid Problems in Mali*. In C.J. Lomer and C. Prior (eds.), Biological Control of Locusts and Grasshoppers. Wallingford, UK, 1992.

[5] Khalil, R.A., Grasshopper Species in the Sudan. *Training course on desert locust Control in Collaboration with Plant Protection Directorate and AOAD*, 1996, Khartoum, Sudan.

[6] Benson, G.J., Dambe, D., Darnhofer, T., Gommes, R. Mwongela, G.N. Pedgley, D.E. and Péramaud., V., Extreme Agro-meteorological Events. *CAgM, Report No.73.WMO/TD*, 1997, No. 836. Geneva, Switzerland.

[7] Luong-Skovmand, M.H., Plan de cours Soudan. *Training course on grasshopper population dynamics*, 2005, (7 October–6 November, Montpellier, France).

[8] Fisker, E.N., Bak, J. and Niassy, A. "A Simulation Model to Evaluate Control Strategies for Grasshopper *Oedaleus senegalensis* in West Africa". *Crop Protection*, 2007, 26(4): 592-601.

[9] Cheke, R.A., A Migrant Pest of the Sahel: The Senegalese Grasshopper, *Oedaleus senegalensis.* Phil. Trans. R. Soc. Lond, 1990, B328: 539-553.

[10] Falk, K., Jensen, F.P., Christensen, K.D. and Petersen, B.S., "The Diet of Nesting Abdim's Stork Ciconia abdimii in Niger". *Bio one*, 3006, 29(2): 215-219.

[11] Petersen, B.S., Christensen, K.D. Falk, K., Jensen, F.P. and Ouambama, Z. "Abdim's Stork Ciconia abdimii Exploitation of Senegalese Grasshopper Oedaleus senegalensis in Southeastern Niger". *Waterbirds*, 2008, 31(2): 159-168.

[12] Axelsen, J. A. "Simulation Studies of Senegalese Grasshopper Ecosystem Interactions I: The Ecosystem Model". *International Journal of Pest Management*, 2009, April: 85-97.

[13] Berges, J.C., Chiffaud, J. and Mestre, J. "Contribution of Spatial Remote to the Identification of Zones Favorable to the Senegalese Locust in the Sahel". *Veille climatique satellitaire*, 1992, 40: 25–33.

[14] Burt, P.J.A., Colvin, J. and Smith, S.M. "Remote Sensing of Rainfall by Satellite as an Aid to *Oedaleus senegalensis* (Orthoptera: Acrididae) Control in the Sahel". *Bulletin of Entomological Research*, 1995, 85: 455-462.

[15] Colvin, J., *Biotic and Abiotic Factor Affecting the Population Dynamics of the Senegalese Grasshopper, Oedaleus senegalensis*. In S. Krall, Peveling, and D. Ba Diallo (eds.), New Strategies in Locust Control. Birkhauser: Verlag Basel, 1997.

[16] Chandra, S., "Some Field Observations on a Small Concentration of *Oedaleus senegalensis* Krauss (Orthoptera: Acrididae) in the Indian Desert". *Plant Pro. Bull.* 1983, 35: 9-13.

[17] Amatobi, C.I., Apeji, S.A. and Oyidi, O., "Effects of Farming Practices on Populations of Two Grasshopper Pests (*Kraussaria Angulifer* Krauss and *Oedaleus senegalensis* Krauss) (Orthopter: Acrididae) in Northern Nigeria". *Tropical Pest Management*, 1988, 34(2): 173-179.

[18] Colvin, J., and Holt, J. "Model to Investigate the Effects of Rainfall, Predation, and Egg Quiescence on the Population Dynamics of the Senegalese Grasshoppers *Oedaleus senegalensis*" (original language French). *Secheresse (Montrouge)*. 1996, 7(2): 145-150.

[19] Jago, N.D., Light Trap Sampling of the Grasshopper *Oedaleus senegalensis* (Krauss, 1877) (Acrididae: Oedipodinae) and Other Species in West Africa: A Critique. *Proceedings of the 2nd Triennial Meeting of the Pan American* Acridological Society, Bozema, US, 1979, 165-198.

[20] Popov, G.B. "Sahelian Grasshoppers. Overseas Development" *Natural Resources Institute Bulletin*, 1988, 5: 87 London.

[21] Maiga, I.H.; Lecoq, M.and Kooyman, C. Ecology and managemen of the Senegalese grasshopper *Oedaleus senegalensis*(Krauss 1877) (Orthoptera: Acrididae) in West Africa: review and prospects. *Ann.Soc.Entomol.Fr.* (n.s), 2008, 44(3):271-288.

[22] Coop, L.B., Croft, B.A., Murphy, C.F and Miller, S.F. Decision support system for economic analysis of grasshopper treatment operations in the African Sahel. *Crop protection*, (1991), 10 (12):485-495.