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Assessing the Loss and Damage in Seeds of some Forest Tree Species due to Infestation of *C. chinensis*, in Kordofan Region, Sudan

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ABSTRACT

Kordofan is considered as one of the most important areas in Sudan for producing leguminous seeds. Bruchids are the most important pests that are responsible for damage in stored and forest leguminous seeds. This study was conducted with the objectives of seeing the variations and their host associations in Kordofan. Field and laboratory investigations targeting the distribution and abundance of bruchids and the qualitative and quantitative losses caused by them. Field surveys were done. Weight loss/100 in Hashab seeds was 0.17%. Mesquite seeds did not host of C. chinensis in the laboratory. The total weight loss and number of holes/100 seeds in Hashab seeds were 3.75, respectively. The germination percentage of Hashab seeds was found to be 60% in the control. Finally, this study makes available data on the range differences among family Bruchidae and their host associations, which may pave the way for ecologically sound management in the future. This study recommended significant care toward these pests due to their economic effect with regard to hashab trees and other forest tree species.

Keywords: *Acacia Senegal, bruchids, gum Arabic, legumes, Kordofan*

1.0 INTRODUCTION

Bruchid species are important storage pests, causing serious storage losses among smallholder farmers. In the absence of any control measures, farmers indicated that more than 50% of their stored beans could be lost by bruchids. Lack of control of insect populations can lead to important economic and environmental losses [1]. There is increasing emphasis on diversifying and intensifying legume production in the developing countries as a useful option towards improving protein intake in the human diet and augmenting food supplies [2]. Every country is making concerted efforts to augment its agricultural production to meet the demand of an ever-increasing population. Loss of 13 million tons due to insects alone and a total of 100 million tons due to improper storage were encountered during the last few years [3]. Pulses ranked second after cereal crops, nicely complementing them, in feeding the people in the developing world. Leguminaceae include approximately 600 genera, with about 1300 species, out of which only about10-12 are of economic importance [4]. Pulse species, besides groundnuts and soybeans, that are of major importance include members of the genera, *Vigna, Phaseolus*, *Cajanus, Cicer, Pisium, Vicia, Lens* and *Dolichos*. These legumes are considered to be an important source of protein to most people in the tropics. Legumes are symbionts of nitrogen-fixing bacteria that form root nodules and indirectly increase the level of soil nitrogen. Hence, they are important components of any balanced crop rotation, particularly in the traditional agricultural sector. Also, they provide much-needed Vitamins, minerals, and fiber to humans. Some genera of legumes are, also, sources of drugs, and gum E.g *Acacia.* Legumes are the meat substitute for the poor, in the third world and the medicine for the over-carnivorous in the first and second world [5].

The country's forest covers about 67 million hectares or approximately 28 percent of total land cover. The savanna zones suffer from large-scale tree clearance, repeated floods during the rainy seasons, erosion, seasonal fires, and sometimes conflict between nomadic herders and farmers. Little information is available about insects and disease impact on forests in Sudan. One report, however, estimated that 102874 km^2 of forested areas in four states-Darfur, Kordofan, Eastern and Central were affected by insect pest and disease [6]. Seeds affected in this way will germinate very badly or not at all. Species of the genus *Callosobruchus* and *Caryedon* are very damaging pests of stored and forest leguminous seeds in Kordofan areas. Data on the extent of infestation, damage, loss, and control under different storage conditions are rather scanty. No information is, however, available on the field status of these pests, especially on leguminous crops in terms of percentage pod/seed infestation, quantitative losses, its carryover to stores and the effect on seed germination. This study attempts to analyze these aspects of bruchid beetles' infestation on leguminous crops, in terms of distribution all over Kordofan state as well as the performance of some species of bruchids on legume seeds. This study aimed to assess loss and damage in some forest tree species seeds due to infestation of *C.chinensis* and to list the group of insects in the family Bruchidae in different sites of study areas that is associated with forest tree seeds.

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It also aimed to produce a structure map for the relative distribution of the species in Kordofan.

2. MATERIALS AND METHODS

2.1 Research sites

South Kordofan site was represented by, *Talodi*, (10 38N°), *Kadugli* (11 00N°), *Lagawa* (11 24N°), *Abu-Gubeiha* (11 27N°) and *Elfolla* (11 42N°). The Middle Kordofan site was represented by *Gibeish*, (12 08N°) and *Um Ruwaba* (12 53N°). North Kordofan site was represented by *Bara*, (13 41N°) and *Sodary*, (14 24N°). The average rainfall of *Talodi*, Kadugli, *Lagawa*, *Abu Gubeiha* and *Elfolla* were 792.4, 764, 631.2, 675.8, and 479.3 mm/annum, respectively. The rainfall of *Gibeish* and *Um Ruwaba* were 352 and 298, respectively. While the rainfall of Bara and Sodary was 270, and 39 mm/annum, respectively (Table 3.1).

Table (3.1): Location of the study sites

Location	GPS data	Temperature (C^0)	R.H%	*Rainfall (mm)*
Talodi	N 10 38 E 30 23	28- 32.3	43-45	*792.4 in 2007 and 2008*
Kadugli	N 11 00 E 29 43	32.3- 34.8	43.8-46.6	*764 in 2007 and 2008*
Lagawa	N 11 24 E 29 07	29- 34	48-50	*570-700* *631.2 in2011*
Abu Gubeiha	N 11 27 E 31 14	23.7- 37.3	31.7-39.2	*675.8 from 2004-2008*
Elfolla	N 11 42 E 28 20	32.3- 35	38.3-40	*479.3 from 2008-2010*
Gibeish	N 12 08 E 27 19	29.5- 36	49-50	*352 in 2011-2012*
Um Ruwaba	N 12 53 E 31 12	32.5- 36	32-39.5	*298 in 2011-2012*
Bara	N 13 41 E 30 22	31- 34	33-40	*270 from 1960-2000*
Sodary	*N 14 24* *E 29 06*	*33- 39*	*38-42*	*39 in 2011-2012*

GPS = Global Positioning System

2.2 Field work and survey

A survey for insects associated with legume seeds in the three sites was carried out during February to June 2009. For each site legume seeds were collected. The source for the seeds were trees, the local market, and / or local stores. Seeds were kept in cloth bag (25 ×30 cm) and transferred to the laboratory. At the laboratory, bruchid insects were separated and preserved in Alcohol /Glycerol mixture (9:1). Insects were identified at the insect museum, ARC, *Wad-Medani*, Sudan. The findings, were expressed in a structural map and key for the separation of the encountered bruchid species.

2.3 Laboratory work

2.3.1 Preparation of the stock cultures

The study was carried out in the laboratory of Crop Protection, Faculty of Natural Resources and Environmental Studies, University of Kordofan. The mean temperature and relative humidity were 32.5± 2.5 C° and 37.5± 2.5%, respectively. The cowpea beetles *Callosobruchus chinensis* and *Callosobruchus maculatus* were collected from a chickpea lot obtained from Elobeid local market during the season 2008/2009. The variety "black eyed cowpea" was used as a media for rearing *C. chinensis* and *C. maculatus.* Seeds were purified manually to get rid of impurities, shriveled, damaged and broken seeds, and the sound seeds were kept in an oven set at 60 C° for ten minutes to disinfest them and then stored at room temperature for seven days for reconditioning before being used to establish a new culture [7].

Seeds were placed in cloth bags (30×35 cm) and then inoculated with a number of adults, where several generations were produced. Cloth bags were periodically checked and fresh sterile cowpea seeds were added to serve more adults, and to avoid overcrowding and the development of moulds.

2.4 Assessment of loss and damage due to *Callosobruchus chinensis*

2.4.1 Preparation of legumes

Lots of 4 kg of different legumes of season 2008/2009 were manually purified to give sound seeds. Grains were put in an oven, set at 60C°for ten minutes to disinfest them. The lots were stored for seven days for reconditioning as stated above in 3.2.1. Then grains were put into lots of two hundred and fifty grams. Each lot was contained in a pot. The pots were disposable and used for soft drink. From each pot 100 seeds were weighed as a reference and then taken back to the same pot. The legumes included cowpea, pigeonpea, chickpea, *hashab* and mesquite.

2.4.2 Preparation of insects

A sample of grains from stock culture was taken. Adults' insect was separated using a seive (3 mm size). The adult free lot was kept for 24 hrs. Then newly emerged adults (≤ 24 hours) were collected for experimentation, using an Aspirator.

2.5 Execution of the Experiments

Pots were inoculated by 10, 15 or 20 pairs of newely emerged adults of *C. chinensis*. In addition, a control (insect free) was used. Each pot was covered with a piece of cloth which was tied with a rubber band. Treatments were replicated four times. The experiments were kept under laboratory condition for 16 weeks.

Temperature and relative humidity

Temperature and relative humitidy were recorded daily at afternoon time, using a digital multifunctual measuring device, (digital, hygro-thermometer) model Human Gmph, brand Human, made in Germany.

Quantitative data

As stated above, 100 seeds were taken from each pot, then weighed and put back to the same pot. This procedure was done every four weeks during the experimental period. The balance used was a sensitive balance. Model DHAUS, brand Adventure, made in China.

Qualitative data

Number of holes

The one hundred seeds, stated above, were checked for damage indicated by exit holes. The number of holes per 100 seeds were counted and recorded seeds were taken back to its original pot.

Germination test

At the end of the experiments (16 weeks) a germination test was executed. From each treatment, 4 petri dishes furnished with moist filter paper (9 cm) were prepared. Each petri dish was inoculated with 10 seeds and kept 3-10 days, depending on type of legume seeds. Then germination percentages were recorded.

2.6 Statistical analysis

The data were analyzed using, analysis of variance using the computer program MSTAT and Duncan's multiple range tests was used for means separation.

3. RESULTS

3.1 Field survey

3.1.1 South Kordofan Latitude 10 38 - 11 42

Table (4.1b) shows infestation of bruchid on Acacia spp in different surveyede areas. *C. serratus* was reported on seed of *Hashab* in all areas. But the insects were not found, except in *Kadugli* and Abu Gubeiha. *C. serratus* also, infested *Sunut* seed in all areas, but the insects were not found. *Talh* seed, was infested in all areas with *C. serratus* except in Lagawa. *Kitr* seed were infested in all areas, except in *Kadugli*, and the insects were found in *Abu Gubeiha*. *Kakamout* seed was infested in all areas. Laot seeds were infested in Kadugli, Lagawa and *Abu Gubeiha*, but the insect were not found in other areas. *Saljum* seeds were infested in *Kadugli* and *Elfolla*, but insects were not found in all areas. Table (4.1c) Bruchid species associated with some trees species seeds in various locations in Southern part of the Kordofan region**,** shows the Tamarind seed was infested.

With *C. serratus* in all areas, and the adults were found in all areas, except in Kadugli. *C.maculatus* infested the seed of *Kaddad* in all areas, but the adults were not found except in Lagawa. Arad in Kadugli Babanous seed in *Abu Gubeiha* and *Elfolla*, were infested but the insects were not found. *Kulkl* seed in Talodi was infested by bruchid, but the insects were not found. *Goldmore* seed in Kadugli, *Abu Suruj* and *Gughan* seed in Elfolla were not infested.

3.1.2 Middle Kordofan

C.chinensis and *C.maculatus*, were found associated with their host in all areas under survey of Middle Kordofan (Table 4.2a). The two insect species were reported on cowpea seed in *Gibeish* and *Um Ruwaba*. While *C. serratus* was reported on groundnut, in *Gibeish*. However, adults were not found in *Um Ruwaba*. *C.chinensis* and *C.maculatus*, also, were also reported on chickpea seed in all areas. Broad bean seed was infested with bruchid in all areas, but the insects were not found. *C. chinensis* and *C. maculatus,* were also reported on Pigeonpea seed in *Gibeish*. However, adults were not found in *Um Ruwaba*. Phaseolus seeds were infested in *Gibeish* and it was insect-free in *Um Ruwaba*. However, adults were not found in *Gibeish*. *C. serratus* was reported on seed of *Hashab* in all areas (Table 4.2b.). But the insects were not found in *Um Ruwaba*. *C. serratus* also infested *Sunut* seed in all areas, but the insects were not found in *Gibeish*. *Dign elbasha* in *Um Ruwaba*, was infested with bruchid, but the insects were not found. *Kitr* seed were infested in all areas and the insects were found in Um Ruwaba. *Aradeib* seed was infested in all areas, but the adults of *C. serratus* were found only in *Gibeish*. *Haraz* seeds were infested in *Gibeish*, but the insects were not found.

Table (3.1): Location of the study sites

Location	*A. Senegal* (*Hashab*)		*A. nilotica* (Sunut)		*A. seyal* (*Talh*)		*A. mellifera* (*Kitr*)		*A. polyacantha* (*Kakamout*)		*A. nubica* (*Laot*)		*A.gerrardii* (*Saljam*)	
	Damage	Spp	Damage	Spp	Damage	Spp	Damage	Spp	Damage	Spp	Damage	Spp	Damage	spp
Talodi	F	NF	F	NF	F	Cocoon of *C.s*	F	NF	F	Cocoon of *C. s*	-	-	-	-
Kadugli	F	Cocoon of *C. s*	F	NF	F	*C.s*	-	-	F	Cocoon of *C. s*	F	*C. s*	**F**	**NF**
Lagawa	F	NF	F	NF	F	NF	F	NF	F	Cocoon of *C. s*	F	NF	-	-
Abu Gubeiha	F	*C .s*	F	NF	F	Cocoon of *C.s*	F	Cocoon of *C. s*	F	*C. s*	F	*C. s*	-	-
Elfolla	F	NF	F	NF	F	Cocoon of *C.s*	F	NF	F	Cocoon of *C. s*	-	-	**F**	**NF**

F=found, NF=not found, C.s= Caryedon serratus (Oliv), - =Plant is not present

Table (4.1c): Bruchid species associated with some trees species seeds in various locations in Sourthern part of Kordofan region, season 2009/2010

Location	*Tamarindus indica* (*Aradeib*)		*Dichrostachys cinerea* (*kaddad*)		*Albizia amara* (Arad)		*Dalbergia melanoxylon* (*Babanouse*)		*Bauhinia rufscens* (*Kulkal*)		*Delonix regia* (*Goldmore*)		*Prosopis africana* (Abu *suruj*)		*Diospyros mespiliformis* (*Gughan*)	
	Damage	Spp	Damage	Spp	Damage	Spp	Damage	Spp	Damade	spp	Damage and SPP		Damage and Spp		Damade and Spp	
Talodi	F	*C.s*	F	NF	-	-	-	-	F	NF	-		-		-	
Kadugli	F	*NF*	F	NF	**F**	NF	-	-	-	-	NF		-		-	
Lagawa	F	*C.s*	F	*C. m*	-	-	-	-	-	-	-		-		-	
Abu Gubeiha	F	*C.s*	F	NF	-	-	F	NF	-	-	-		-		-	
Elfolla	F	*C.s*	F	NF	-	-	F	NF	--	-	-		NF		NF	

F=found, NF=not found, C.s= Caryedon serratus (Oliv), - =Plant is not present

Table (4.2b): Bruchid species associated with some Acacia tree species seeds in various locations in Middle part of Kordofan region, season 2009/2010.

Location	*A. senegal* (*Hashab*)		*A. nilotica* (*Sunut*)		*Albizia lebbek* (*Dign elbasha*)		*A.mellifera* (*Kitr*)		*Tamarindus indica* (*Aradeib*		*Faidherbia albida* (*Haraz*	
	Damage	Spp	Damage	Spp	Damage	Spp	Damage	Spp	Damage	Spp	Damage	Spp
Gibeish	F	Cocoon of *C. s*	F	NF	-	-	F	NF	F	C.S	F	NF
Um Ruwaba	F	NF	F	*C. s*	F	NF	F	*C. s*	F	NF	-	-

F=found, NF=not found, C.s= Caryedon serratus (Oliv), - = tree is not present

3.1.3 North Kordofan

C.chinensis and *C.maculatus*, were found associated with their host in all areas under survey of North Kordofan (Table 4.3a). The two insects and their damage were reported on cowpea seed. While *C. serratus* was reported on groundnut in the Bara. *C.chinensis* and *C.maculatus*, were not reported on chickpea seed in the two areas. Broad bean seed was infested with bruchid in all areas, but the insects were not found. *C.chinensis* and *C.maculatus* also were reported on pigeonpea seed in *Sodary*. However, adults were not found in Bara. Phaseolus seed were insect-free. *C. serratus.* was reported on seed of *Hashab* in all areas (Table 4.3b.). But the insects were not found. *C. serratus* also infested *Sunut* seed in a ll areas, but the insects were not found in Bara. *Bruchus baudoni* was found to be associated with it in Sodary. Seyal seeds in *Sodary* were infested, but insects were not found. *Kitr* seed in Sodary were infested with *C.serratus*, but the insects were not found in Bara. *Aradeib* seeds were infested in all areas, but the insects were not found in Sodary. *Laot* seeds, were infested in *Sodary*, but the insects were not found. *Haraz* seeds were infested in all areas, but the insects were not found.

Insect identification

The bruchid species were found associated with their host in all areas under survey. It revealed an extremely high infestation. Figure (4.1) showed the distribution of some bruchid species in the Kordofan region, which as was follows:

1. *Callosobruchus chinensis* (L.).
2. *Callosobruchus maculatus* (Fabricius).
3. *Caryedon serratus* (Olivier).
4. *Bruchus baudoni* (Caild).

Table (4.3b): Bruchid species associated with some tree species in various location in Northern part of Kordofan region, season 2009/2010.

Location	*A.senegal* (*Hashab*)		*A.nilotica* (*Sunut*)		*A.tortilis* (*Seyal*		*A.mellifera* (*Kitr*)		*Tamarindus indica* (*Aradeib*		*A. nubica* (*Laot*)		*Faidherbia albida* (*Haraz*)	
	Damage	Spp	Damage	Spp	Damage	Spp	Damage	Spp	Damage	Spp	Damage	spp	Damage	spp
Bara	F	NF	F	NF	-	-	F	NF	F	C.s	-	-	**F**	**NF**
Sodary	F	NF	F	*C.s* +Bb	F	NF	F	*C .s*	F	NF	F	NF	**F**	**NF**

F = found, NF = not found, C.s = Caryedon serratus, Bb= Bruchus boudoni - = tree is not present.

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3.2 Laboratory work

3.2.1 Loss in weight/100 seeds of *Hashab* and *Mesquite* due to infestation by *C. chinensis*

3.2.1.1Loss in weight/100 seeds of *Hashab* (in grams)

Table (4.7) showed that there was no significant difference (P=0.05) in the weight of seeds among different treatments in the first count, after 4 weeks and in the subsequent counts, until the end of the experimental period, 16 weeks. The mean percentage total weight loss was 0.0%. *Hashab* showed no significant difference in infestation at different level of infestation and at different time of infestation.

3.2.1.2 Loss in weight /100 seeds of *Mesquite* (in grams)

The results obtained indicated that there was no significant difference in weight among different treatments in the all counts, at 4 weeks intervals for a period of 16 weeks. The mean percentage of total weight loss was 0.0%.

Table (4.7): Effect of various number of C. chinensis on Hashab

Treatment	Weight of 100 seeds (grams)				% loss in wt-16 weeks
	4 weeks	8 weeks	12 weeks	16 weeks	
10 pairs	10.68 [a]	10.43 [a]	10.35 [a]	10.28 [a]	0.01
15 pairs	10.68 [a]	10.53 [a]	10.44 [a]	10.36 [a]	0.00
20 pairs	10.61 [a]	10.37[a]	10.24 [a]	10.19 [a]	0.02
Control	10.36 [b]	10.23 [a]	10.29 [a]	10.30 [a]	0.00
SE±	0.05	0.05	0.05	0.05	-
C V%	1.37	2.01	1.94	1.87	-

Mean in the same column followed by the same letter are not significantly different at (P≤0.05) according to Duncan's Multiple Range Test (DMRT).

3.3 Qualitative data

3.3.1 Number of holes/100 seeds of *Hashab*

Table (4.11) showed that there were no significant differences (P=0.05) in number of holes among different level of infestation especially at the end of the experment, starting (after 4 weeks)

and in the subsequent counts, until the end of the expermintal period (16 weeks). There were no significant differences in number of holes at different lenghth of time in all levels of infestation and number of holes increased when more time was given to infestation. The subsequent counts, until the end of the experimental period (16 weeks). Also, no increase in infestation was reported on *Hashab* with time.

3.3.2 Number of holes/100 seeds of Mesquite

The results obtained indicated that there was no hole in the different
treatments starting from the first count (after 4 weeks) until the end of theexpermintal period (16 weeks).

Table (4.11): Effect of various number of C. chinensis on Hashab

Treatment	Number of hole / 100 seeds			
	4 weeks	8 weeks	12 weeks	16 weeks
10 pairs	1.75 [b]	2.50 [b]	3.25 [a]	3.25 [a]
15 pairs	2.75 [a]	3.50 a	3.50[a]	3.75[a]
20 pairs	2.25[a b]	3.50 [a]	3.75 [a]	3.75[a]
Mean	2.25 B	3.17 A	3.5 A	3.58 A
LSD	0.4	0.4	0.4	0.4
C V%	25.66	21.05	17.39	16.11

Mean in the same column followed by the same letter(s) are not significantly different at (P≤ 0.05) according to Duncan's Multiple Range Test (DMRT)

3.3.3 Germination test

showed the mean germination percentage *Hashab* seeds. When treated with different level of *C. chinensis*. It was 60% in the untreated control.

DISCUSSION

4.1 Field surveys

Hashab, Sunut, Taleh, *Kitr Kakamout, Laot, Saljam, Seyal, Tamarindus, Kaddad, Arad, Haraz, Babanouse, Dign elbasha,* and *Kulkul* were infested with bruchids (whereas prevailed). These results were in line with other studies on *Acacia senegal* and *Albizia lebbek* [8,9]. *Tamarind* pods as a main host for the bruchid and it develops more quickly when bred on its pods than on unshelled groundnuts [10]. He further added that *C. serratus* does not breed on cotton seeds or cowpeas. The other report include: several species of wild tree legumes, four species of *Acacia*, four species of *Bauhinia*, three spp of *Cassia, Piliostigma spp*, and *Tamarindus indica* [11, 9]. The most suitable host for multiplication of *C. serratus* was found to be *Tamarind*, followed by groundnut [12].

The infestation of Mesquite seed with *C. serratus* began when the pod began to ripen and continued until seeds matured. A similar view was also expressed [13] who reported that *Caryedon longuidus* larvae fed on *P. cineraria* seed. While *Goldmore*, *Abusruj* and *Gughan* seeds were found to be incapable to infestation by any Bruchid, this is solely due to:

(i) Antibiosis: The presence of compounds that inhibit oviposition and the development of insects [14].

(ii) Physical structure (1): seed testa made difficulties encountered by the hatching larvae and by the emerging adult in penetrating through the seed coat. This result was in line with [15] who reported that the thickness of the seed-coat seems to be only limiting factor significantly reducing infestation by *C.chinensis* during storage.(2): Tightness of the glumes in unmilled Rice [16, 17] which serve as a physical barrier working against penetration by insects. Hardness of seeds [18] was thought to make insect penetration more difficult thus, providing protection. (3) seed size [19] had also been shown to influence infestation by insect pests as large grain legumes provide more surface area for oviposition and larval development than small–sized grains; (4) the texture and hairiness of the coats of Cowpea seed; may have negative influence on the oviposition of the Cowpea weevil [20]. (5): the quantity and quality of nutritional constituents have been described to have an influence on the fecundity of the females, the developmental period of the pre-imaginal instars and the rate of adult emergence [21].

4.2 Laboratory work

4.2.1 Loss in weight/100 seeds of *Hashab* and *Mesquite* due to infestation of *C.chinensis* (in grams)

In *Hashab* and Mesquite, there was no significant difference (P=0.05) in weight of seeds among different treatments in the first count. This was probably due to the time needed by *C.chinensis* to develop. At the beginning, the population size was slow and by the time it progressed so rapidly. It is worth to mention that Lack of control of insect populations can lead to important economic and environmental losses [1]. *Hashab* seed showed very low susceptibility, and *Mesquite* seed showed resistance to this beetle for developing in the laboratory. There were no significant differences in the weight among different treatments in the first count and in the subsequent counts. This probably may be due *Hashab* and *Mesquite* seeds are not preferred to *C. chinensis* to develop. The mean percentage total weight loss in all treatments was 0.0%. But the eggs were laid on the seeds. A similar view was also expressed [18] who examined a large number of non-host leguminaceae and found that the hardness and chemistry of the seed coat may be important as a barrier to entry of *C. maculatus.* The inability of the insect to develop on *Hashab* and *Mesquite* seeds may be because their seed coat could not be penetrated by the larvae. Similar view was also expressed by [15] who claimed that the relative resistance of some varieties of Broad beans (*Vicia faba*) to *C. chinensis*, is solely due to difficulties encountered by hatching larvae and by the emerging adult in penetrating through the seed-coat. The thickness of the seed coat seems to be a limiting factor. Also, the testa may contain toxins and failure of the larvae to survive. The toxicity of the testa provides an effective barrier to protect the seed.

4.2.2 Qualitative data

4.2.2.1 Number of holes /100 seeds of *Hashab* and *Mesquite* due to infestation of *C.chinensis*

The inability of the insect to develop on *Hashab* seed may be because their seed coat could not be penetrated by the larvae, or the test may be so thick that the newly hatched larva dies before it reaches cotyledon, or the cotyledon may be too hard to penetrate or poisonous. A similar view was also expressed [18]. The mean total numbers of holes/100 *Mesquite* seeds infested by *C.chinensis* in all treatments showed no variation, constituted zero holes/100 seeds, The inability of the insect to develop on *Mesquite* seed may be because as stated in 5.2.1.1.1. The result indicates that the Mesquite seed were not host to *C. chinensis* in the laboratory.

4.2.2.2 Germination test

In *Hashab* seed, the treatments of 15, and 20 pairs gave the best result with 70%. The remaining treatments which had a germination percentage of 60 and 50%. This result indicated that the few holes made by bruchids increase absorption of water, and accelerate germination. High infestation by bruchid beetles could present a serious problem for seed germination.

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The results of this study showed that the loss and damage in *Hashab* due to the infestation of *C. chinensis* was significant. *C.chinensis, C.maculatus*, *B. boudoni* and *C.serratus* were found in different sites of the Kordofan region, in forest and legumes.

5.2 Recommendation

This study recommended significant care toward these pests due to their economic effect with regards to *hashab* trees and other forest tree species.

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