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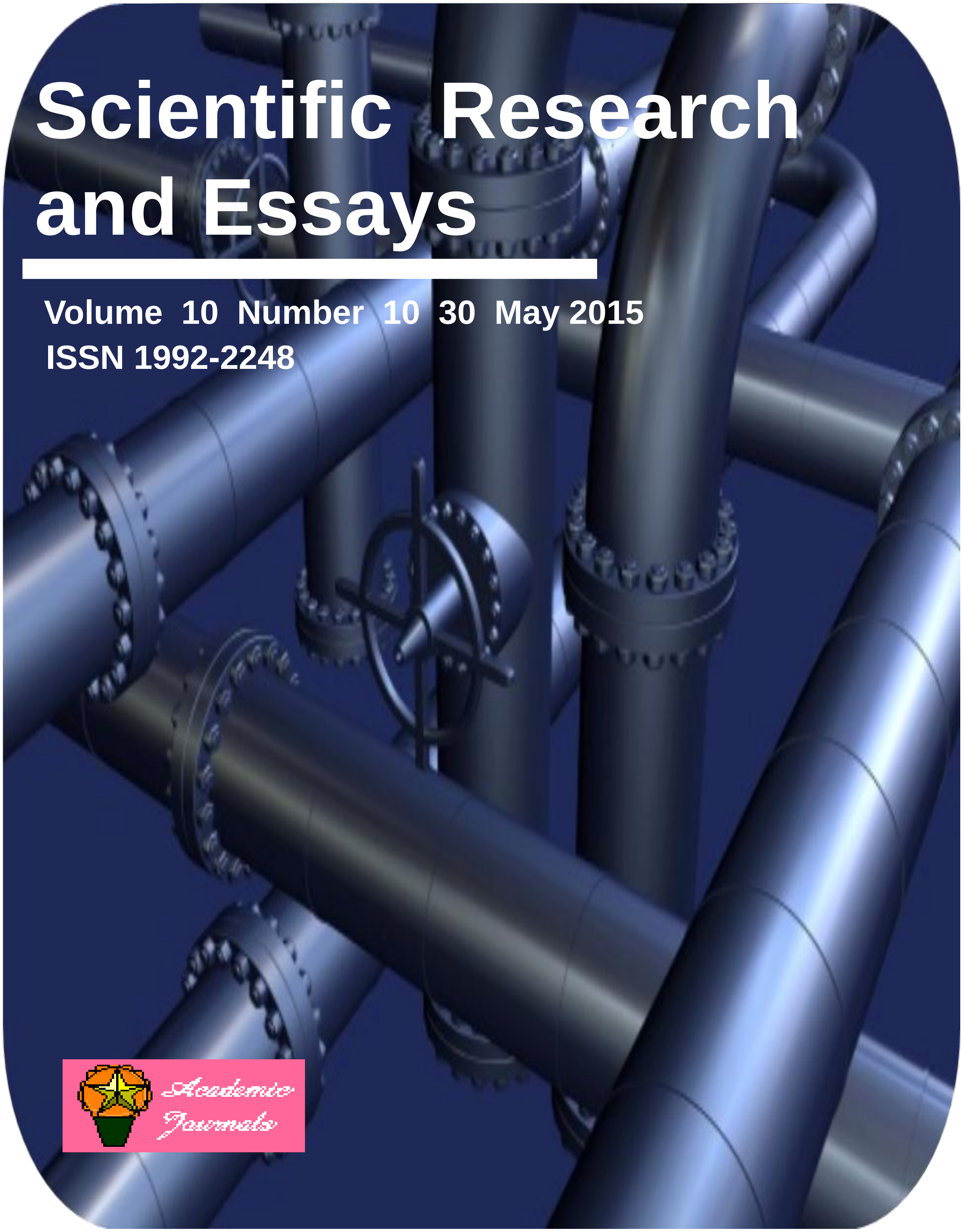

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Scientific Research and Essays

Full Length Research Paper

The mating behaviour of the banana weevil, *Cosmopolites sordidus* Germar (Coleoptera : Curculionidae)

Richard P. Uzakah* and Johnson A. Odebiyi

Department of Crop Protection and Environmental Biology, University of Ibadan, Oyo State, Nigeria.

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The banana weevil, *Cosmopolites sordidus* Germar mates repeatedly in its lifetime. No elaborate courtship behavior was seen before mating in the laboratory. However, 'sniffing' (an activity by which male weevils used their antennae to contact the abdominal tip of the female, as if to perceive some stimulus), often preceded mating. This observation may be an indication of a chemical pheromone involved in the mating behaviour of this insect. Male banana weevils generally displayed aggressive mating behaviour. Matings occurred under both light and dark conditions, but significantly more in the dark. A direct and positive linear correlation was observed between mating and sniffing under both light and dark conditions. Similar trends or correlations were observed between mating and mating duration; mating and sniffing durations respectively.

Key words: *Cosmopolites sordidus*, courtship, sniffing, pre-copulatory, copulatory, mating behavior.

INTRODUCTION

The banana weevil, *Cosmopolites sordidus* Germar, is recognized globally as the major insect pest of banana and plantain (Ostmark, 1974; Reddy et al., 2008; Tinzaara et al., 2011). It attacks all species of the genus *Musa*, and no cultivar in this group is known to have total resistance to the insect's larva (or borer) (Wolcott, 1933; Simmonds, 1966; Gold et al., 2001). Certain cultivars, however, are known to be more susceptible to the pest than others (Wolcott, 1933; Feakins, 1971; Viswanath, 1981; Mesquita et al., 1984; Gold et al., 2001). The 'Lacatan' variety for instance, is less susceptible, while 'Maduranga' is more susceptible (Viswanath, 1981). Plantains and highland bananas are also more susceptible to the weevil than desert or brewing bananas (Gold et al., 2001).

Damage from the pest includes eating up of large portions and growing points of the corm, and setting up of secondary rots from which the plant scarcely recovers (Simmonds and Simmonds, 1953); reduced vitality and drought resistance, poor bunch development and 'snapping' (pseudostem breakage around the base of the plant) (Harris, 1947). Gold et al. (2001) reported a reduced nutrient uptake, weakened plant stability and crop failures for newly established farms following larval activities; while established farms experienced reduced bunch weights, mat die-out and shortened stand life.

*Corresponding author. E-mail: rikuzakah@yahoo.com.

Damage and yield losses were also increased with time. In spite of the economic importance of this pest, detailed information on its reproductive biology is lacking. Pavis (1988) similarly reported that the details of its sexual behaviour are unknown. Up till date, there has been no detailed published work on the subject. This study was therefore conducted to provide information on the mating and sexual behaviour of this pest.

MATERIALS AND METHODS

The mating behaviour of *C. sordidus* was studied in the laboratory using Petri dishes (9.5 cm diameter) and bigger plastic containers (20 cm diameter × 10 cm high) that contained moist sand, because the weevil is known to prefer moist or humid conditions (Roth and Willis, 1963). The Petri dishes contained a pair of weevils (a male and a female), and the larger containers held groups of 5:5 or 10:10 males and females respectively, to tract the behaviour of individual mating pairs in particular and those that were grouped.

Observations were made both under dark* and lighted conditions of the laboratory (that is, about 1000 lux, 24 ± 2°C and r.h. of ≈ 80%) in a 12:12 L:D photoperiod with scotophase starting at 9 am; during the hours of 09.00 and 14.00 hours daily (that is, 5 h of close observation daily). Prior to start of trials (between 7 and 9 am), the weevils were thoroughly washed and sorted according to sex, using the methods of Longoria (1968) (rostrum punctuations) and Roth and Willis (1963) (curvature of the last abdominal sternite); as adopted by other Researchers too (Budenberg *et al.,* 1993a, b; Gold et al., 2001). Freshly collected males from the field were paired with lab-reared females in all trials, except where otherwise stated; as earlier laboratory observations found them to mate more eagerly and readily.

Light and dark conditions represented treatments, and ten (10) trials or observations were made under each condition (light and dark condition) everyday (each trial lasting 30 min (that is, a total of 10 trials per treatment in each day). Each treatment was replicated four (4) times (that is, repeated over 4 days). Data consisted of qualitative descriptions of the weevil's pre-copulatory and copulatory behaviours; and quantitative accounts on time spent in mating.

The Dark room had a single light fluorescent source covered with a Red filter (Kodak Wratten No. 70, admitting wavelengths > 640 nm). The dim light permitted observations without any apparent disturbance to the insects. The method was adapted from Budenberg et al. (1993a, b).

Statistical analysis

The observed incidences of mating and sniffing; and the durations of mating and sniffing in the light and dark conditions were subjected to simple T-tests to see if differences were statistically different. The hypothesis was that light and dark had no effect on weevil mating. Differences were deemed to be significant at $P < 0.05$. Correlation analysis was also done to determine the relationships between these observations (the correlation matrix is presented in Tables 7 and 8).

RESULTS

Before mating, males generally displayed no elaborate or detectable courtship behaviour. On coming into contact with each other, the male mounted the female from any angle possible (from the head, rear or sides). If mounting was initiated from the female's head (Figure 1a), the male usually proceeded to sniff the female's abdominal end with its antennae (Figure 1c). It periodically raised its antennae up, and soon afterwards resumed the sniffing behaviour, as if perceiving some chemical signal. This activity usually lasted for periods of a few seconds 0.3 to 3 min (μ = 0.3 min ± 0.10 SE, n = 40) in dark conditions (Table 1). In light conditions, 0.6 to 2.1 min (μ = 0.22 min ± 0.07 SE, n = 40) (Table 2). Immediately afterwards, the male usually turned around to adopt a copulatory position, on top of the female and facing in the same direction (Figure 1f). In this position, the male firmly grasped the female and lifted the latter's abdominal end with its hind legs, curving its abdomen inwardly to insert its aedeagus into the female's vulva, thus commencing mating.

At other times however, the males first drummed its antennae on the female's head and pronotal area, and soon after slid backwards to engage genitalia with the female after lifting the females abdominal end with its hind legs. Most males that mounted from the female's rear usually displayed this behaviour. Sniffing was not common among these males; rather, they usually just stroked the back of the female. Receptive females remained still, and the males immediately slid backwards to commence mating. This antennal stroking on the back of the female, might be the only observable 'courtship' behaviour in these insects.

Males that mounted from the side of the female, often quickly maneuvered themselves into appropriate copulatory positions, after first sniffing the abdominal end of the female and stroking the female's head area, or both; or none of these at other times.

During copulation, the male was observed on top of the female with its legs grasping the female's sides, and with its head, thorax and the upper half of its abdomen raised from the female's body; the male's lower abdomen was tightly engaged with that of the female (Figure 1f) and close observation revealed genital contact. Mating (time spent in copula) usually lasted for a period ranging between 0 to 20.1 min (in dark conditions, μ = 3.98 min ± 0.76 SE, n = 40) (Table 1). In light conditions = 0 to 6.1min (μ = ≈1 min ± 0.29 SE, n = 40) (Table 2). However, it was not unusual to find mating pairs in apparent copulatory positions for periods of >1hr, but without any genital contact. Before and sometimes during mating, certain females tended to walk away or disengage from mounted males. Such males usually responded quickly by stroking the back of the females with their antennae, which often induced them to resume mating. Unreceptive females usually repelled males by running rapidly while mounted, which dislodged them, or by kicking at them with their hind legs.

In the bigger containers with several mating pairs, an aggressive mating behaviour was observed. Most males mounted and attempted to mate with virtually every

Table 1. Banana weevil matings, mating duration, sniffing and sniffing duration in dark condition.

S/N	Mtg	Md	Snf	Sd
1	1	5	1	0.5
2	0	0	0	0
3	0	0	0	0
4	1	12.4	1	3
5	1	3.2	0	0
6	1	11.3	1	1.1
7	1	5.8	0	0
8	0	0	0	0
9	1	7.2	0	0
10	1	8.3	1	0.8
11	0	0	0	0
12	0	0	0	0
13	1	4.2	0	0
14	0	0	0	0
15	0	0	0	0
16	1	14	0	0
17	1	5.6	0	0
18	0	0	1	0.3
19	1	8.3	1	1.1
20	0	0	0	0
21	1	3.1	1	0.5
22	0	0	0	0
23	1	7	0	0
24	0	0	0	0
25	1	5.2	0	0
26	0	0	0	0
27	0	0	0	0
28	1	20.1	1	0.5
29	0	0	0	0
30	1	4.2	0	0
31	1	3.2	1	2.1
32	1	4.1	0	0
33	0	0	0	0
34	1	6.2	1	1.2
35	0	0	0	0
36	0	0	0	0
37	1	3.2	1	0.6
38	1	10.1	0	0
39	1	7.3	0	0
40	0	0	0	0
∑	22	159	11	11.7
µ	0.55	3.975	0.275	0.293
SE	0.88	0.756	0.072	0.1003
Var	0.254	22.85	0.204	0.402
N	40			

weevil they contacted (male or female) , and disturbed other weevils in copula, by attempting to also mate with them. These intruding males sometimes first sniffed the abdominal end of the female in copula, and then climbed on top of the pair in an attempt to mate. This behaviour often led to an aggregation of weevils around or on top of a mating pair, which resulted in premature disengagements, as the female tried to break free from the crowd of males.

Males that attempted to mate with other males usually faced distinct resistance as the assaulted male often kicked to repel the aggressive male. However, it was not uncommon to find two males mounting each other and adopting copulatory positions. Males mated repeatedly with either the same or other females. Time interval between matings (re-mating time interval) was highly variable and in-fact difficult to track, especially amongst grouped weevils (because of their gregarious and aggressive nature). So amongst the same pairs, it could occur approximately 1 to 2 h after the first successful mating, whilst already mated males could mount another female and attempt to mate with it within approximately 30 min.

Several observations in the laboratory revealed that freshly collected field weevils tended to be more aggressive and eager to mate than those maintained or reared in the laboratory. They mated more readily and also more frequently compared with those from the laboratory colonies. Matings were observed under both light and dark conditions, although significantly more frequent in the dark (T-stat 2.841 > T-tab 1.665; $P < 0.005$, n = 80 (Table 3).

Mating duration was similarly significantly longer in the dark compared to light conditions ($P < 0.001$; n = 80) (Table 4). No significant differences were observed in sniffing incidents in the dark or light conditions (T-stat 0.781^{ns} < T-tab 1.665; $P > 0.05$; n = 80, Table 5). Neither was differences in sniffing duration (comparing light and dark conditions) found to be significant (T-stat 0.588^{ns} < T-tab 1.666; $P > 0.05$; n = 80, Table 6).

A direct and positive linear correlation was however, observed between mating and sniffing, both under dark and light conditions (r = 0.445**; $P < 0.01$ 1-tailed; n = 40) (r = 0.433**, $P < 0.01$, 1-tailed, n = 40) (Tables 7 and 8, respectively). Similar trends or correlations followed mating and mating duration; mating and sniffing duration.

DISCUSSION

Both sexes of the banana weevil, *C. sordidus* mate repeatedly in their lifetime. Khairmode et al. (2015) also found both sexes of the two known banana weevil pests (that is, *C. sordidus* and *Odoiporus longicollis* Oliver, both Coleoptera: Curculionidae) to be polygamous; Martins *et al*. (2013) also reported re-matings in the rice water weevil, *Oryzophagus oryzae.* Repeated matings in *C. sordidus*, involving the same or different partners were a

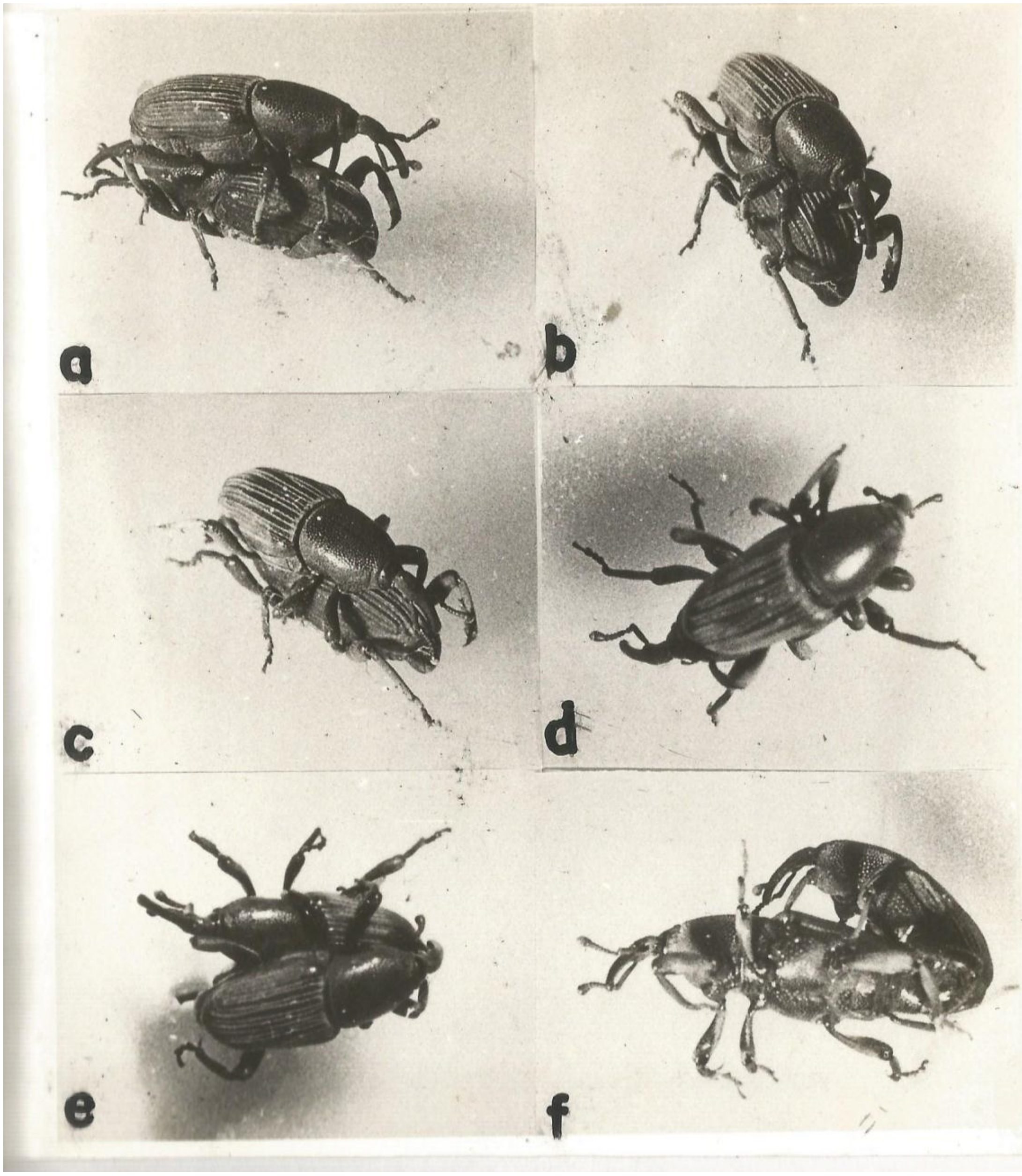

Figure 1. Different stages in the mating behaviour of the banana weevil, *Cosmopolites sordidus* (Mag x3). (a) and (b) = male mounts female from the latter's head; (c) = male sniffs female's abdominal end; (d) and (e) = male prepares to turn around for mating; (f) = A close-up of male and female banana weevil in copula.

common sight in this study. The significance of this observation is not clear. Cuille (1950) reported that insemination in this insect is needed only once per year, as isolated females were capable of ovipositing continuously for a period of 11 months without further insemination. However, after cessation of oviposition, introduction of males provoked a resumption of egg laying. The fact that these insects are long-lived (4 years, Rukazambuga et al., 1998) would support the need for females to replenish their sperm reserves. Sperm replenishment after multiple matings is a common phenomenon in some insects such as *Drosophila melanogaster* (Pyle and Grombo, 1978).

The significance of multiple matings to the banana weevil, could be for increased fecundity. As Hinton (1981) noted, many species, including most Coleoptera, require more than one mating for maximum fecundity, and as a rule, male insects are capable of inseminating females throughout the females' lifetime. He further stated that species that live for several years are able to inseminate

Table 2. Banana weevil matings, mating duration, sniffing and sniffing duration in Light condition.

S/N	Mtg	Md	Snf	Sd
1	0	0	0	0
2	0	0	1	1.1
3	1	4.2	1	0.4
4	0	0	0	0
5	1	3.1	0	0
6	0	0	0	0
7	0	0	0	0
8	1	2.8	1	2.1
9	0	0	0	0
10	1	5.1	0	0
11	0	0	0	0
12	1	4	0	0
13	0	0	0	0
14	0	0	0	0
15	0	0	0	0
16	0	0	0	0
17	0	0	0	0
18	0	0	0	0
19	1	2.9	1	0.7
20	0	0	0	0
21	0	0	0	0
22	1	6.1	0	0
23	0	0	0	0
24	0	0	0	0
25	1	3	1	1.5
26	0	0	0	0
27	0	0	0	0
28	0	0	0	0
29	0	0	0	0
30	1	3.7	0	0
31	0	0	0	0
32	0	0	0	0
33	0	0	1	0.6
34	1	5	1	1.3
35	0	0	0	0
36	0	0	0	0
37	0	0	0	0
38	0	0	1	1
39	0	0	0	0
40	0	0	0	0
∑	10	39.9	8	8.7
μ	0.25	0.99	0.2	0.22
SE	0.069	0.289	0.06	0.07
Var	0.192	3.349	0.164	0.25
N	40			

Mtg = Mating; Md = mating duration; Snf = sniffing; Sd = sniffing duration.

females each season, but that as the male grows older, its capacity declines. Johnson and Hays (1969) observed that females of the plum curculio, *Conotracchelus nenuphar*, produced more eggs when mated two or three times than when mated only once. Repeated matings in the milkweed beetle, *Tetropes tetraopthalmus* (Forster) increased female fecundity and fertility (Lawrence, 1990).

The banana weevil, *C. sordidus* is known to be nocturnal (Cuille, 1950; Reddy *et al*., 2008; Khairmode *et al*., 2015); not surprisingly, dark conditions in this study were found to be more favourable for mating incidents and for longer durations too, than the lighted conditions. But contrary to Khairmode et al. (2015) report of matings only at night, the insect was seen mating under both light and dark conditions of the lab. The reason for this behaviour is presently not known. but might be associated with its gregarious and polygamous nature.

The sniffing behaviour of male weevils before mating, and the absence of copulatory attempts with freeze-killed weevils by males in the laboratory trials (Uzakah, 1995), showed that olfaction and some form of mechanical stimulus (perhaps movement) seemed to be necessary for mating to occur in these insects. Male weevils apparently are sexually aroused or activated only after some form of movement by the females. Similar observations were made in the tsetse fly, *Glossina morsitans orientalis* (Dean et al., 1969). These observations were however, contrary to those of Selander (1978) and Tiles et al. (1988) who recorded copulatory attempts with freeze-killed pine weevils, *Hylobius abietis* (L). The sniffing behaviour of males before mating suggests that females of this insect release a sex pheromone that stimulates the males to mate. Cross and Mitchell (1966) noted that male boll weevils *Anthonomus grandis* Boheman responded to females at distances not greater than ≈ 5 cm, and they speculated that the females produced a weak secondary pheromone that attracted other males. Ravi and Palaniswami (2002) also reported presence of aggregation and sex pheromone in the closely related banana weevil, *Odoiporous longicollis* Olivier. The reason for the occasional male-to-male mating attempt in *C. sordidus* was not clear, but it could be caused by contamination with female emissions or may be simply representative of the aggressive nature of the males. Aggregation of both sexes is a common feature in this insect, following a release of a male produced aggregation pheromone (Budenberg et al., 1993a); but actual mating seems to be precipitated by the release of a female sex pheromone as evidenced from the pre-copulatory sniffing behaviour of the males. Sex and aggregation pheromones are common amongst weevils (Tinzaara et al., 2002). According to these authors, pheromones and other behaviour modifying chemicals (e.g. kairomones) hold a great potential as tools for pest management; as they could be useful in pest monitoring, and also as

Table 3. t-Test comparing banana weevil matings in dark and light conditions (assuming unequal variances).

Variable	Dk Mtg	Lght Mtg
Mean	0.55	0.25
Variance	0.25384615	0.192308
Observations	40	40
Hypothesized mean difference	0	
Df	77	
t Stat	2.84059246**	
P(T<=t) one-tail	0.00287931	
t Critical one-tail	1.66488454	
P(T<=t) two-tail	0.00575862	
t Critical two-tail	1.99125436	

Dk Mtg = Matings in dark condition; Lght Mtg = matings in light condition.

Table 4. t-Test comparing banana weevil mating durations in dark and light conditions (assuming unequal variances).

Variable	Dk Md	Lght Md
Mean	3.975	0.9975
Variance	22.85269	3.348968
Observations	40	40
Hypothesized mean difference	0	
Df	50	
t Stat	3.678895***	
P(T<=t) one-tail	0.000287	
t Critical one-tail	1.675905	
P(T<=t) two-tail	0.000573	
t Critical two-tail	2.008559	

Dk Md = Mating duration in dark condition; Lght Md = mating duration in light condition.

Table 5. t-Test comparing banana weevil sniffings in dark and light conditions (assuming unequal variances).

Variable	Dk Snf	Lght Snf
Mean	0.275	0.2
Variance	0.204487	0.164103
Observations	40	40
Hypothesized mean difference	0	
Df	77	
t Stat	0.781303^{ns}	
P(T<=t) one-tail	0.21851	
t Critical one-tail	1.664885	
P(T<=t) two-tail	0.43702	
t Critical two-tail	1.991254	

Dk Snf = sniffings in dark condition; Lght Snf = sniffings in light condition.

control measures through mating disruptions, mass trapping and even as means for aggregating herbivores to delivery sites for biological control agents. They therefore called for further exploits in the synergism

Table 6. t-Test comparing banana weevil sniffing durations in dark and Light conditions (assuming unequal variances).

Variable	Dk Sd	Lght Sd
Mean	0.2925	0.2175
Variance	0.40225	0.248147
Observations	40	40
Hypothesized mean difference	0	
Df	74	
t Stat	0.588169^{ns}	
P(T<=t) one-tail	0.279105	
t Critical one-tail	1.665707	
P(T<=t) two-tail	0.55821	
t Critical two-tail	1.992543	

Dk Sd = Sniffing duration in dark condition; Lght Sd = sniffing duration in light condition.

Table 7. Correlation matrix of banana weevil matings, mating duration, sniffing and sniffing duration (in dark conditions).

Parameter		Mtg	Md	Snf	Sd
Mtg	Pearson correlation	1	0.762**	0.445**	0.398**
	Sig. (1-tailed)		0.000	0.002	0.005
	N	40	40	40	40
Md	Pearson correlation	0.762**	1	0.443**	0.415**
	Sig. (1-tailed)	0.000		0.002	0.004
	N	40	40	40	40
Snf	Pearson correlation	0.445**	0.443**	1	0.758**
	Sig. (1-tailed)	0.002	0.002		0.000
	N	40	40	40	40
Sd	Pearson correlation	0.398**	0.415**	0.758**	1
	Sig. (1-tailed)	0.005	0.004	0.000	
	N	40	40	40	40

**Correlation is significant at 0.001 level (1-tailed); * Correlation is significant at 0.05 level (1-tailed); Mtg = Mating; Md = Mating duration; Snf = sniffing; Sd = sniffing duration.

Table 8. Correlation matrix of banana weevil matings, mating duration, sniffing and sniffing duration (in light conditions)

Parameter		Mtg	Md	Snf	Sd
Mtg	Pearson correlation	1	0.956**	0.433**	0.449**
	Sig. (1-tailed)		0.000	0.003	0.002
	N	40	40	40	40
Md	Pearson correlation	0.956**	1	0.343**	0.335**
	Sig. (1-tailed)	0.000		0.015	0.017
	N	40	40	40	40
Snf	Pearson correlation	0.433**	0.343**	1	0.884**
	Sig. (1-tailed)	0.003	0.015		0.000
	N	40	40	40	40
Sd	Pearson correlation	0.449**	0.335**	0.884**	1
	Sig. (1-tailed)	0.002	0.017	0.000	
	N	40	40	40	40

**Correlation is significant at 0.001 level (1-tailed); * Correlation is significant at 0.05 level (1-tailed); Mtg = Mating; Md = Mating duration; Snf = sniffing; Sd = sniffing duration.

between banana plant extracts (kairomones) and the synthetic pheromone in attracting the banana weevil, *C. sordidus*.

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Conflict of Interest

The authors have not declared any conflict of interest.

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Scientific Research and Essays

Full Length Research Paper

Etio-pathological investigations to study the gross and histopathological lesions affecting gastrointestinal tract of sheep

S. Kumar[1], K. K. Jakhar[1] and A. D. Singh[2]*

[1]Department of Veterinary Pathology, Lala Lajpat Rai University of Veterinary and Animal Sciences (LUVAS), Hisar-125004, India.
[2]Department of Veterinary Anatomy, Guru Angad Dev Veterinary and Animal Sciences University (GADVASU), Ludhiana- 141004, India.

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Thirty sheep/lambs were brought for post mortem in Teaching Veterinary Clinical Complex, LUVAS and Central Sheep Breeding Farm, Hisar, which were investigated for gastrointestinal tract pathology in laboratory of Department of Veterinary Pathology. Mortality was maximum in sheep/lambs of age group 6 months to 1 year and higher in males than females. Gross pathological changes in gastro intestinal system noticed were congestion in abomasum, intestine, pancreas, liver and mesenteric lymph nodes. Histopathologically, there was congestion, desquamation of mucosal epithelium, submucosa in abomasum and small intestine including goblet cell hyperplasia. Congestion along with mild necrosis in pancreatic acini, liver parenchyma, peri portal area and mesenteric lymph node was observed along with haemorrhage in peri portal area and thrombosis of portal blood vessel in liver. Cloudy swelling, fatty changes, centrilobular necrosis in parenchyma and bile duct hyperplasia in liver was also reported.

Key words: Gastro-intestinal, gross changes, histopathology, sheep.

INTRODUCTION

Gastrointestinal tract disorders (GIT) play an important role in causing high mortality and morbidity in sheep affecting the profits in sheep production programmes (Lamy et al., 2012). Some of the diseases are Johne's disease (paratuberculosis), *Escherichia coli* diarrhoea, Salmonellosis, *Clostridium prefringens* type- B, C (enterotoxaemia) and type-D, bloat, diarrhoea and Peste des petits ruminants (PPR) (Tefera et al., 2009). Mortality in sheep/lambs causes a great deal of concern to sheep breeders, leading to poor economic returns. Certain diseases like gastro-enteritis causes heavy mortality and adversely affect the profits in livestock production programmes (Carrigan and Seaman, 1990; Doghaim et al., 2000). For the prevention and control of gastrointestinal tract disorders in sheep, it is desirable to know etiology

*Corresponding author. E-mail: dramandeep287@gmail.com, Tel: +91-9781072259.

Table 1. Age and sex wise distribution of mortality due to various gastrointestinal pathological lesions among sheep/lambs.

Age	No. of cases	Sex	
		Male	Female
< 2 months	3/30 (10%)	3/30 (10%)	-
2 months-5 months	4/30 (13.3%)	3/30 (10%)	1/30 (3.3%)
6 months -1 year	18 /30 (60%)	12 /30 (40%)	6/30 (20%)
> 1 year	5/30 (16.6%)	4 /30(13.3%)	1/30 (3.3%)
Total	30/30	22/30 (73.3%)	8/30 (26.6%)

Table 1 indicates maximum mortality in sheep/lambs were found in age groups of 6 months to 1 year group and in male sheep/lamb.

and clinico-pathological aspects of gastrointestinal tract disorders. The present study had been formulated on etio-pathological investigations to study the gross and histopathological lesions affecting gastrointestinal tract of sheep.

MATERIALS AND METHODS

Thirty sheep/lambs were brought for post mortem in Teaching Veterinary Clinical Complex, LUVAS and Central Sheep Breeding Farm, Hisar, which were investigated for gastrointestinal tract pathology in laboratory of Department of Veterinary Pathology. The percent cases of mortality due to various pathological conditions in different age groups (< 2 months, 2-5 months, 6 months -1 year and > 1 year), sex and affected gastrointestinal tract was analysed. The gross pathological studies were conducted at the time of collection of tissue specimens and the lesions were recorded. The tissues were taken to the laboratory of Department of Veterinary Pathology and preserved in 10% formal saline. From the most representative sites tissues showing pathological lesions were taken, processed and sectioned at 4 to 5 µ thickness and staining is done using Lily Mayer's haematoxylin and 2% water soluble eosin (Luna, 1968). Histo-pathological lesions were recorded and compared within age groups, sex and organs of gastrointestinal tract.

RESULTS

Age wise distribution of mortality in sheep/lambs has been presented in Table 1 and which indicates that maximum mortality was found in age group of 6 months to 1 year (18/30, 60%) followed by >1year (5/30, 16.6%), 2 to 5 months (4/30, 13.3%) and < 2 months age group (3/30, 10%). Sex wise distribution of mortality in sheep/lambs has been given in Table 1. It showed that overall mortality was more in males than female sheep/lambs. To specify further, mortality in age group of < 2 months was (10% in male, 0% in females), 2 to 5 months (10% in males and 3.3% in females), 6 months to 1 year (40% in males and 20% in females) and >1 year (13.3% in males and 3.3% in females). Overall mortality in males was 73.3% and in females was 26.6%. The main gastrointestinal affections were enteritis and hepatitis.

The gross pathological changes observed in different organs are depicted in Table 2 shows that in gastrointestinal tract, congestion was the most prominent change seen in intestine (9 cases) (Figure 1) followed by abomasum (5 cases) (Figure 2) and liver (4 cases) (Figure 3). Other pathological lesions include catarrhal enteritis (5 cases) (Figure 4) and necrotic foci in liver (3 cases) (Figure 5). Major microscopic lesions in gastrointestinal tract found were congestion of abomasal mucosa and submucosa (Figure 6) followed by desquamation of mucosal epithelium, mild congestion in mucosa and submucosa, goblet cell hyperplasia and mucosal glands filled with leucocytes (Figure 7) in small intestine. In mesenteric lymph node, cystic spaces due to excess depletion of lymphocytes and severe congestion in cortex (Figure 8) were evident. Congestion with mild necrosis of pancreatic acini (Figure 9) was also reported. In liver, thrombosis of portal vessel (Figure 10), cloudy swelling and congestion of portal triad (Figure 11), haemorrhage in hepatocytes (Figure 12), bile duct hyperplasia (Figure 13), haemorrhage in periportal area and centrilobular necrosis in liver (Figure 14) was observed.

DISCUSSION

Mortality in male sheep/lambs was comparatively higher than in females were in confirmation with Lashari and Tasawar (2011) findings. The possible reason for the present findings is that testosterone indirectly induces the immunosuppression by increasing the level of corticosteroids which is a stress hormone as in accordance with Gauly et al. (2006). Mortality in 6 months to 1 year may be higher due to over eating of green pasture by rapidly growing lambs leading to more access to parasitic infestation and also due to accumulation of undigested starch and carbohydrates in rumen provide a favourable medium for enterotoxemia while younger lambs < 2 months are dependent on mother's milk/colostrum before weaning, lack exposure to parasitic infestation due to nonfeeding or overfeeding of pasture. Catarrhal enteritis was the most common post-mortem

Table 2. Gross pathological changes observed at post mortem examination of sheep/lambs.

Gross changes	Intestine	Liver	Pancreas	Mesenteric lymph nodes	Abomasum
Congestion	9	4	1	-	5
Haemorrhages	-	-	-	-	-
Necrotic Foci	-	3	-	-	-
Catarrhal enteritis	5	-	-	-	-

Table 2 shows that in gastrointestinal tract, congestion was the most prominent change seen in intestine (9 cases) followed by abomasum (5 cases) and liver (4 cases). Other pathological lesions include catarrhal enteritis (5 cases) and necrotic foci in liver (3 cases).

Figure 1. Photograph of intestine showing mild and severe congestion.

Figure 2. Photograph showing abomasitis due to hemonchosis.

observations in gastrointestinal tract of infected sheep/lambs. These findings were in accordance with reports of Saleim et al. (2004) and Rao et al. (1980). In abomasum, congestion in mucosa and submucosa (Figure 6) observed which were similar to findings of Panisup (1974), Gough and McEcwen (2000), Saleim

Figure 3. Photograph showing severe congestion (red hepatization) in liver.

Figure 4. Photograph of intestine showing catarrhal type of inflammation.

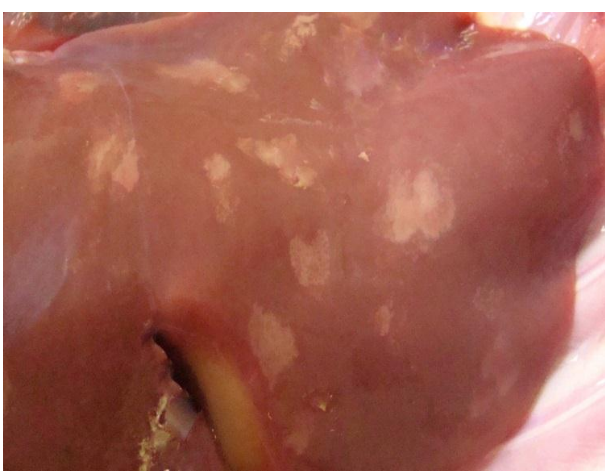

Figure 5. Photograph showing necrotic foci on liver.

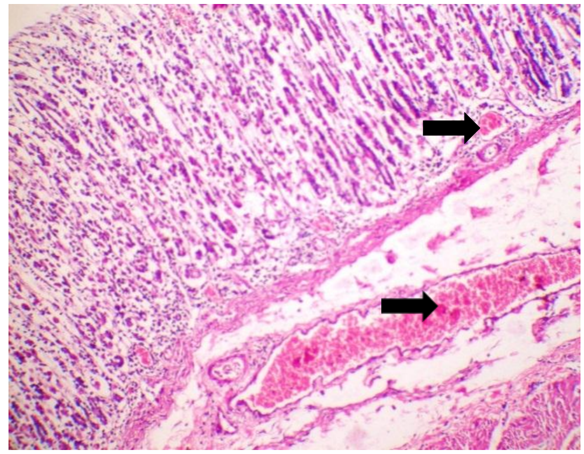

Figure 6. Photomicrograph of abomasum showing congestion in mucosa and submucosa (H&E X100).

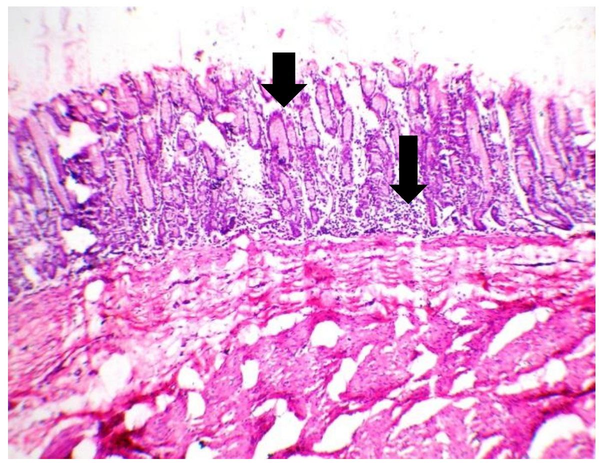

Figure 7. Photomicrograph of intestine showing hyperplasia of goblet cell and mucosal gland filled with leucocytes (H&E X100).

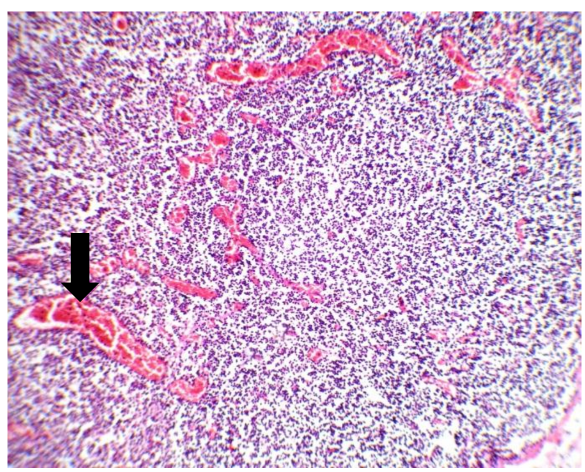

Figure 8. Photomicrograph of mesenteric lymph node showing severe congestion in cortex (H&E X100).

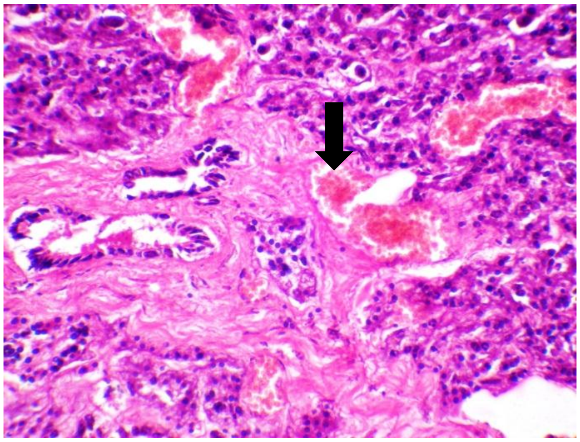

Figure 9. Photomicrograph of pancreas showing congestion with mild necrosis of acinar cells (H&E X400).

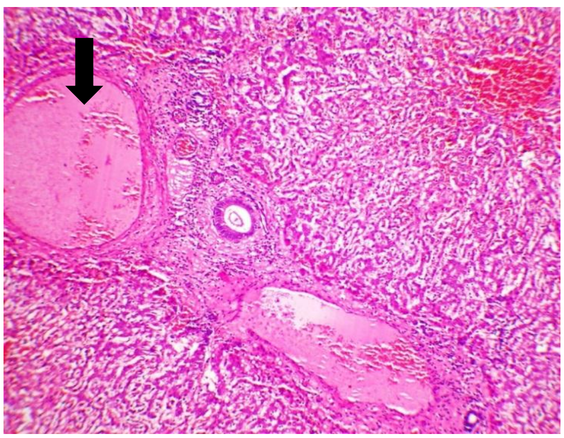

Figure 10. Photomicrograph of liver showing thrombosis in portal vessel (H&E X100).

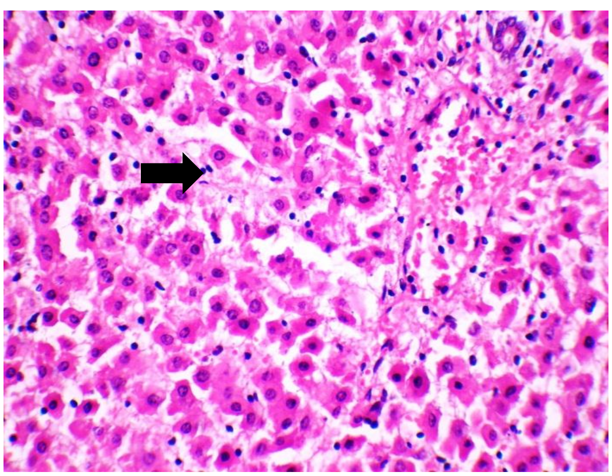

Figure 11. Photomicrograph showing cloudy swelling and congestion of portal vessel of liver (H&E X400).

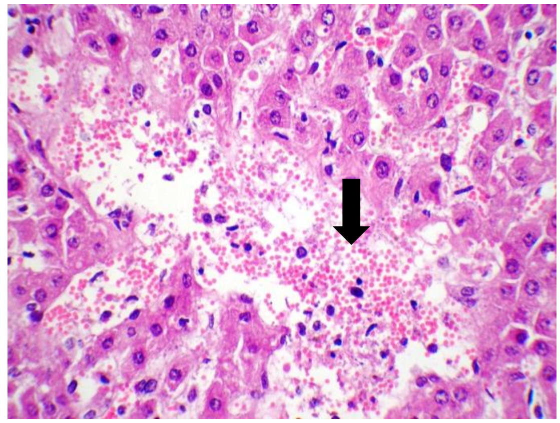

Figure 12. Photomicrograph of liver showing haemorrhage in hepatocytes (H&E X400).

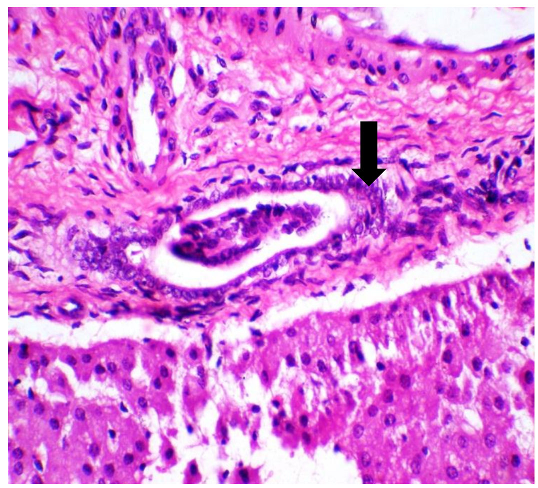

Figure 13. Photomicrograph showing hyperplasia of bile duct (H&E X400).

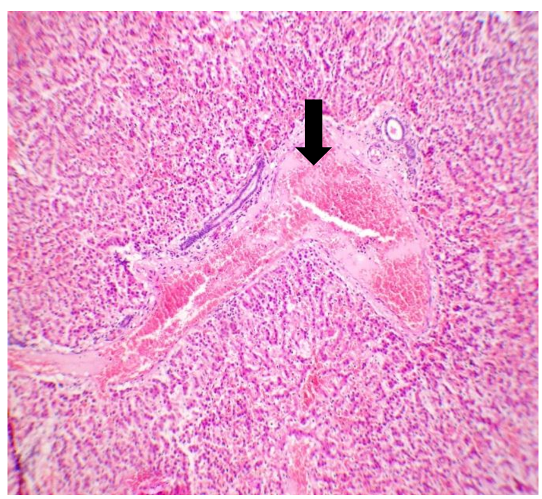

Figure 14. Photomicrograph of liver showing centrilobular necrosis (H&E X100).

et al. (2004) and Tariq et al. (2008). Bile duct hyperplasia (Figure 13) and necrotic changes in parenchyma along with centrilobular necrosis in parenchyma (Figure 14) were in accordance to observation of Saleim et al. (2004). Abomasitis may be due to gastrointestinal parasitism (*Haemonchus contortus*) which increases the serum pepsinogen and gastrin secretion by loss of parietal cell and mucous cell hyperplasia. This further results in secretion of secretory products provoking inflammation and damages abomasal mucosa (Hajimohammadi et al., 2010).

Conflict of Interest

The authors have not declared any conflict of interest.

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Scientific Research and Essays

Full Length Research Paper

Investigations on the photoconductivity studies of ZnSe, ZnS and PbS thin films

S.Thirumavalavan[1], K. Mani[2] and S. Sagadevan[3]*

[1]Department of Mechanical Engineering, Sathyabama University, Chennai-600 119, India.
[2]Department of Mechanical Engineering, Panimalar Engineering College, Chennai-602103, India.
[3]Department of Physics, Sree Sastha Institute of Engineering and Technology, Chembarambakkam, Chennai-600 123, India.

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Zinc selenide (ZnSe), zinc sulphide (ZnS) and lead sulphide (PbS) thin films were prepared by chemical bath deposition (CBD) method. In this paper we report results on the photoconductivity behaviour of ZnSe, ZnS and PbS thin films. Photoconductivity measurements were carried out at room temperature by connecting it in series with a picoammeter (Keithley 480) and a dc power supply. Photoconductivity processes may be the most suitable technique for obtaining information about the states in the gap. The thin films showed a significance rise in photocurrent over dark current. The photoconductive studies reveal the positive photoconductive nature of the thin films. Photoconduction includes generation and recombination of carriers and their transport to the electrodes.

Key words: Thin films, photoconductivity, ZnSe, ZnS, PbS.

INTRODUCTION

Semiconducting thin film materials, which are based on sulfides and selenides, have recently concerned much consideration as materials for optoelectronics technology. Thin films have other useful properties of electrical conduction, optical transmittance, reflectivity, absorption and corrosion resistance. Nanocrystalline semiconducting materials were used in electronic, optoelectronic and solar energy conversion devices. The physical and chemical properties are found to be strongly size dependent (Gray, 2003; Elango et al., 2000). During the recent decades, semiconductor materials are extremely vital in the development of wide range electronic and optoelectronic devices for information applications. A significant property of a semiconductor is its temperature dependence of conductivity, that is, the fact that the conductivity in semiconductors increases with increasing temperature, whereas the conductivity in metals decreases with increasing temperature (Goswami, 2008). One of the key parameters that often determine the range of applications of a given semiconductor is the basic energy bandgap that separates the conduction from the valence bands, which is typically in the range from 0 to 3 eV for semiconductors (Yacobi, 2003). In recent years, research on the preparation and characterization of thin films was developing into a major research area. Thus the electronic industries due to the use of thin films in electronic, opto-electronic and other devices have become the supreme beneficiary of thin film technology.

*Corresponding author. E-mail: drsureshnano@gmail.com.

The use of thin films in manufacture active and passive electronic components made it possible to produce very large-scale integrated and microcomputer. Studies on thin films have been responsible for the development of active and passive components, different types of sensors, solar energy conversion, magnetic memory devices, superconducting films, optical image storing devices, electromechanical devices like strain gauge, gas detecting transducers, interference filters and reflection and antireflection coatings (Joachim et al., 2002; Kalyanasundaram and Graetzel, 2010; Cavaco et al., 2007; Lita et al., 2005; Shinya et al., 2000; Stephen et al., 2004; Pierre, 2002; Koc et al., 2005). In addition to major role to a diversity of new technologies, the thin film studies have many new areas of research in solid state physics and chemistry and will continue to pave the way for a variety of problems of basic and technological importance. Photodetection technology has become very significant in military applications, particularly in guided weapons and communication through fiber optics. Infrared developments are based on solid state photonic devices. Further developments in these fields demand a good understanding of the basic principles of photoconductivity processes. Smith and Sandland (1923) recorded first the photoconductivity effect in 1873 when he observed the decrease in the resistivity of selinium by the radiation shining on it. When the photons of energy greater than that of the band gap of the material are incident upon a photoconductive material, the electrons and holes are created in the conduction and valence bands respectively, increasing the conductivity of the sample. The basic principle involved in photoconductivity is that when photons of energy greater than that of the band gap of the semiconductors are incident on the material, electrons and holes are created resulting in the enhancement of electrical conductivity. This phenomenon is called intrinsic photoconductivity. It is also possible to observe photoconductivity when the energy of the incident photon is less than that of the band gap. When the energy of the photon matches the ionization energy of the impurity atoms, they are ionized, creating extra carriers and hence an increase in conductivity is observed. This phenomenon is called extrinsic photoconductivity. In the present investigation, we report the photoconductivity studies were carried out on Zinc Selenide (ZnSe), Zinc sulphide (ZnS) and Lead Sulphide (PbS) thin films. The variation in field dependent dark and photoconductivity of thin films were studied.

Photoconduction and dark conduction

Photoconductivity is due to the absorption of photons (either by an intrinsic process or by impurities with or without phonons), leading to the creation of free charge particles in the conduction band and/or in the valence band. Photo-absorption and hence photo-conduction takes place by one of the following mechanisms. (i) Band-to-band transitions, (ii) Impurity levels to band edge transitions, (iii) Ionization of donors, (iv) Deep level (located in the valence band) to conduction band transitions. Photoconduction includes the generation and recombination of charge carriers and their transport to the electrodes. Obviously, the thermal and hot carrier relaxation process, charge carrier statistics, effects of electrodes, and several mechanisms of recombination are involved in photoconduction. It gives valuable information about physical properties of materials and offers applications in photodetection and radiation measurements. Dark current (I_d), is the amount of current that flows through the material or device when no radiation is incident on it. It changes with operating temperature and applied voltage, and therefore these parameters should be always mentioned. Dark current is not a constant background current but also has fluctuations or noise. The average D.C. value of the current is generally mentioned as dark current.

MATERIALS AND METHODS

The chemical bath deposition (CBD) method is used to the deposition of a thin film on a substrate from a reaction occurrence in solution. The procedure wants the substrate to be immersed in a supersaturated solution of aqueous precursors. CBD method possesses many advantages over the others method such as its non-sophisticated instrumentation, convenience for large area deposition, applicable to a wide range of substrates, and generally very simple. In particular, chemical bath, method has been used to deposit thin films for present investigation. In this method the substrate was reserved immobile and the solution has been stirred well with magnetic stirrer and the oil bath was used to heat the chemical bath to get a preferred temperature. The process generally operates under ambient conditions and has the potential to replace expensive energy. In chemical bath deposition, the film forms when the substrate is immersed into the solution. The deposition of sulphide and selenide thin films used chemical bath deposition method on the glass substrates. Zinc Selenide (ZnSe), Zinc Sulphide (ZnS) and Lead Sulphide (PbS) thin films were prepared by chemical bath deposition method. The sample is well-polished and surfaces are cleaned with acetone. This is attached to a microscope slide and two electrodes of thin copper wire (0.14 cm diameter) are fixed onto the specimen at some distance apart using silver paint. A direct-current (D.C.) power supply, a Keithley 485 picoammeter and the prepared sample are connected in series as shown in Figure 1. The sample is covered with a black cloth to avoid exposure to any radiation. The current (dark) is measured. To measure the photoconductivity, light from a 100 W halogen lamp is focused onto the sample. The field-dependent dark and photoconductivity studies were carried out using Keithley picoammeter. The applied field was varied and the corresponding current in the circuit was measured.

RESULTS AND DISCUSSION

Photoconductivity is a useful tool to study the properties of semiconductors. It is also considered to be an important tool for providing information about the nature

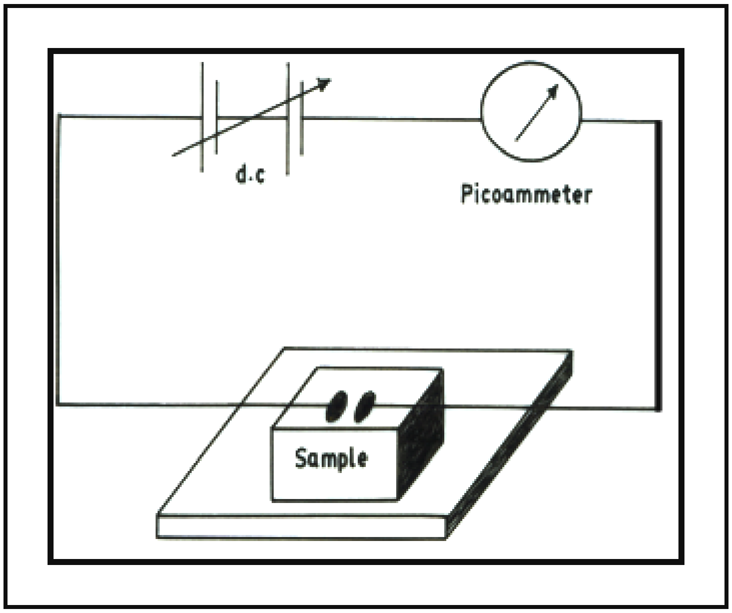

Figure 1. Experimental setup for measuring photoconductivity.

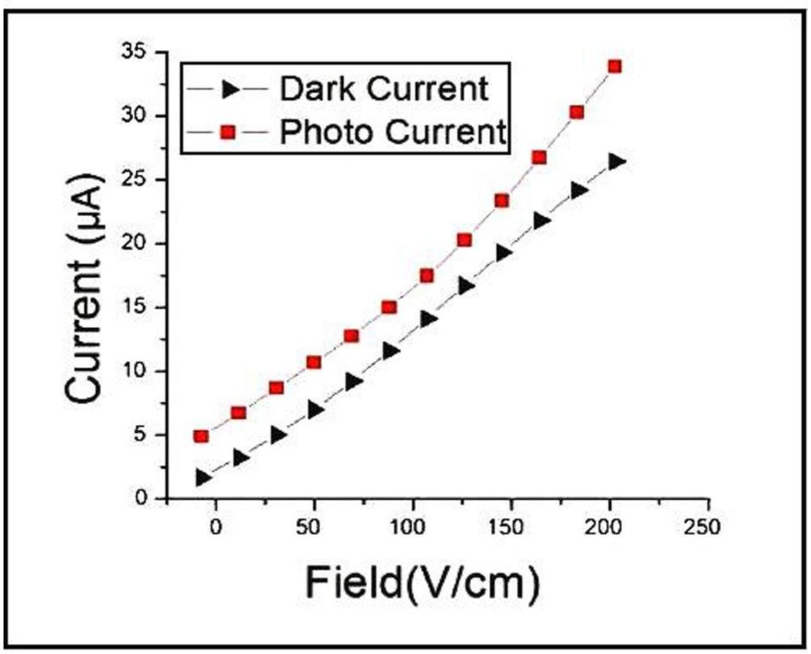

Figure 2. Photoconductivity study of ZnSe Thin films.

of the photo-excitations. A good photoconductive device requires efficient charge separation and efficient transport of charge carriers to electrode. The conductivity of the material depends upon the carrier density and complex process of carrier generation, trapping and recombination. It is also a function of temperature, applied field, intensity of light and energy of radiation. Field dependent dark and photoconductivity plots of ZnSe, ZnS and PbS thin films are shown in Figures 2 to 4 respectively. It is observed that both dark and photo currents increase linearly with the applied electric field with the dark lesser than the photocurrent current which is termed as positive photoconductivity. The plots indicate a linear increase of current in the dark and visible light

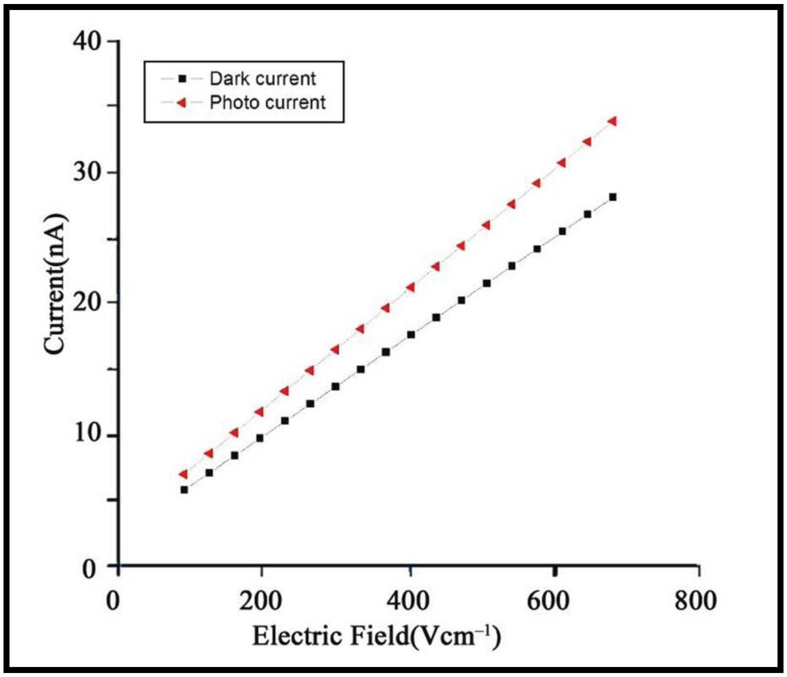

Figure 3. Photoconductivity study of ZnS thin films.

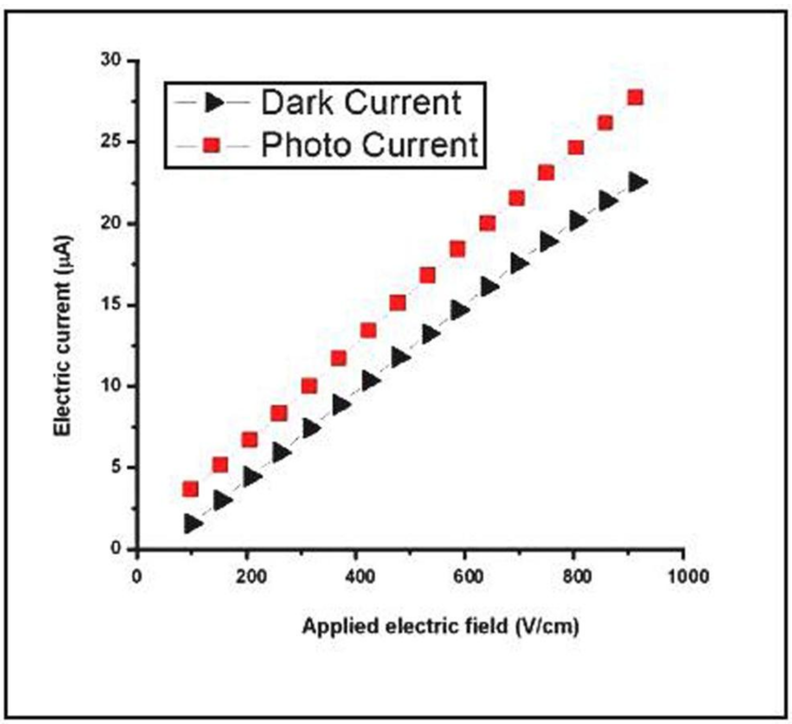

Figure 4. Photoconductivity study of PbS thin films.

illuminated thin films cases with an increase in applied field depicting the ohmic nature of the contacts (Armelao et al., 2003). The low values of dark current and insignificant rise in photocurrent upon the visible light illumination are as expected. But the photocurrent is found to be more than the dark current. Hence, it can be said that the material exhibits positive photo conductivity. This is caused by the generation of mobile charge carriers caused by the absorption of photons. This is because of an increase in the number of charge carriers or their life time in the presence of radiation (Bube, 1981). The start of a charge transfer process where in the photon absorbed and it gives rise to electron injection into the conduction band of the semiconductor films is responsible for the increase in photocurrent. The forbidden gap in the material contains two energy levels in which one is located between the Fermi level and the conduction band while the other is located close to the valence band. The second state has high liberate electrons and holes. As it liberate electrons from the conduction band and holes from the valence band, the number of charge carriers in the conduction band gets complete and the current increase in the presence of radiation. Thus the films is said to exhibit positive photoconducting effect. The positive photoconductivity of the films may be due to the increase in the number of charge carriers to reveal the conducting nature of the material. The dark current was lesser than the photocurrent, signifying positive photoconductivity nature confirmed by the reported results (Thirumavalavan et al., 2015).

Conclusion

The objective of the work is to analysis photoconductivity behaviour of ZnSe, ZnS and PbS thin films. The ZnSe, ZnS and PbS thin films were obtained by chemical bath deposition (CBD) technique. Photoconductivity studies on these films were done. Photoconductivity test is a simple and powerful technique to study energy levels in the band gap of semiconducting material.The photoconductivity studies determine the positive photoconductivity nature of the thin films. The thin films recorded low values of dark and an insignificant rise in photocurrent upon visible light illumination whereas the thin films showed better photocurrent.

Conflict of Interest

The authors have not declared any conflict of interest.

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