Functional Response of Diving Beetles *Dineutus Aereus* (Coleoptera:Gyrinidae) Feeding on Mosquito Larvae Culex Pipiens L.(Diptera:Cuilicidae).

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***Abstract*-** This study was conducted to study predatory efficiency and functional response of females diving beetles, *Dineutus aereus*, when feeding on different densities of second and fourth stages of mosquitoes *Culex pipiens* larvae . . Larval and pupae stages of mosquitoes were treated with predators. Results were observed 24 after treatment,tests were conducted at temperature at 25 ± 2 °C and humidity of 65% ± 5 and 12 hours of illumination, the water beetles of *D.aereus* showed the maximum average consumption of 219.2 ± 15.23 larva / day for larval stage while the pupae stage showed less consumption than the rest of the stages with an average consumption of 69.6 ± 3.19 larva / day . Water beetles *D. aereus* , showed with 20 larvae from the second phase an average daily consumption of 17.20 ± 1.75 larva / day while 120 larvae of the second stage had an average daily consumption of 70.4 ± 8.87 larva / day ,while 20 larvae of the third stage the average daily consumption was 13.5 ± 1.82 larvae / day and 120 larvae from the fourth stage the average daily consumption was 46.5 ± 2.52 larva / day. The increased funtional respone With increased prey density makes us classified the *D.aereus* predator as type II of Holling (1959) division. The results of the study of the time taken by the predator in the search larvae prey for of the second and fourth stages For mosquitoes *C.pipines* that with increasing prey density of the rate from 20 to 120 larvae / predator / day led to a gradual decrease in the time of search for prey

I. Introduction

Biological control is one of the most important components of integrated pest control programs and predators are important biotic agents in reducing populations of insect pests. [1]. Predation of mosquitoes eggs, larvae, and pupae is an essential and important part of eliminating and reducing their numerical density [2] .The larvae and pupae are the most vulnerable to predators, where they are attacked by larvae and adults of water beetles from the family of Dytiscidae of the class Coleoptera [3]. The functional response of the predators was defined as the relationship between predatory density and predation rate within predator and predator system.[4] .It describes the rate at which the predator kills its prey with its different densities, which can determine the predator's efficiency in regulating prey populations, which is an important tool in determining the success or failure of biotic control program [5]. The second type of funtional resopone in which the prey's death is based on reverse density in which the population is very effective and achieves successful biological control [6]. The mosquito *C. pipiens* ais one of the most common types of mosquitoes, if some mosquito larvae survive after predation, they become the most dangerous species in disease transmission [7]. The aims of this study is to show Predatory efficiency and functional response of diving beetles *D.aereus* against the various stage of mosquitoes *C.pipiens*

II. Materials and Methods

Mosquitoes breeding

Multiple ponds have been selected in different locations in Salah AL-ddin Governorate where mosquitoes are frequent in these ponds because they are rich in organic matter. After preliminary water survey, different samples of these ponds were taken to cover the area to be studied, by a long-drawn scoop. Larvae and pupae were placed in plastic containers perforated to allow air access and were transferred to the laboratory and emptied into glass basins and supplied with chlorine-free water and yeast to feed larvae (30 mg per basin) and covered with soft membrane . [8]The study was conducted on labarotery conditions at tempertures 25 ± 2 C , relative humidity 65% ± 5 and a 12 hour / day illumination period to the adult stage where mosquitoes were transported to aluminum cages (150 x 100 x 80 cm), designed by the researcher.The adult stages are fed on a concentrated glucose solution 7% continuously and when egg is needed , a pigeon is inserted into the cage because this type of mosquito prefers the pigeon as a source of blood breeding to enable the female to take the blood meal for 12 hours. Plastic vials are then placed inside the cage containing a quantity of water to lay eggs. The eggs are then transferred to metal trays of 30 x 30 cm non-rustic dimensions to breed the larvae after filling them with water and to add food made from bread crumbs and coverd with soft membrane to protect them and not to allow any external insects to lay eggs in water. When the larvae reach the fourth stage and before they can not be moved to the white plastic containers covered with the top with a tightly closed hole and when the complete insects are pulled out by a special suction device. .

Predatores collected

The adult predators water beetles *D. aereus* collected from permanent water ponds and from some drainage channels in Salah AL-ddin Governorate. Predators were collected between December 2017 and July 2018. The predators were kept in the laboratory in glass basins. The dimensions of these glass basins were 60 x 50 x 40 cm. The predators were periodically fed to mosquito larvae until the date of expermination.

Predatory effectivness

To determine the predatory efficacy of predator on the incomplete stages of *C.pipiens* mosquitoes, six treatments were established, four of which included different larval stage of mosquitoes in addition to pupae stage as well as the control . Each treatment included four replicates . Controlled treatment containing the same number of larvae or pupae was without predator. Each tretment is done 300 larvae from each stage of larvae or larvae with one of the predators after being starved for 24 hours in a plastic container 30 x 20 x 10 cm filled with 500 ml of water and 24 hours after counting the number of larvae and pupae .The number of larvae and pupae Consumed by the predator and each larvae or pupae lost are calculated [9].

Functional response to prey density

For the purpose of estimating the functional response, the predator density relationship was used with the predator of the water beetle predators *D.aereus* were used with larvae density of (20, 40 ,60 ,80 ,100 , 120). The same tiend was done with second and fourth stage. as well as a control coefficient. Each treatment included four replicates..The number of larvae killed can be calculated by subtracting the number of larvae before the experiment. After 24 hours of exposure to predators, four replicates were used for the predators and the control treatment without predators. Time can be found in the search for prey according to the equation set by. Ha = a. H. T search [10].
Where = Ha number of larvae consumed a = number of replicates H = larval density in studied repiate T = time of prey.
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Table (1) Effect of Numerical density of prey in the study of the functional response of predator

Predators	The stage of prey	The density of prey
D.aereus	Second star	20,40,60,80,100,120
	Fourth star	20,40,60,80,100,120
	Second star	20,40,60,80,100,120
	Fourth star	20,40,60,80,100,120

III. RESULTS AND DISSCISION

Predatory effectivensess

In this study , Table 2:showed predator *D.aereus* the highest average consumption was 219.2 larvae / day from the first stage, while the pupae stage showed less consumption than the rest of the stages with an average consumption of 69.2 larvae / day of *C. pipiens*(Fig.1). The experimental laboratory efficacy of predators of *D. aereus*, showed an increase in the mean stage of the first larval stage and a gradual decline of this medium in other larval ages and in the pupae phase The predatory ability rate of small-sized species has been highest predation rate , because the front legs of small-sized predators are more likely to catch prey [11]. The number of larvae of mosquito larvae significantly decreased, with all the larvae growing from first to fourth of stage . There was a significant difference in the number of pupae that preyed by predator *D. aereus*, . There was no significant difference between the larvae consumed during the second , and third stages, but the difference was significant between the first stages and others stages. The results showed that the mosquito larvae *C.. pipiens* by predator *D. aereus*, which was inversely proportional to the larval age under laboratory conditions. The highest predation efficiency was compared stages to the first and second larval stages and significantly decreased the third and fourth larvae for all predators. This was due to the higher nutritional value for the first and second stages compared to the third and fourth stages [12].
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Table 2: Mean average efficiency of predator *D.aereus* against *Cx.pipiens* under laboratory conditions

Predator	Larvae stage	Average predator ± standard deviation
D.aereus	First larval stage	219.2 ± 15.23 a
	Second larval stage	132.8 ± 11.81 b
	Third larval stage	122 ± 9.55 b
	Fourth larval stage	93.4 ± 8.2 b
	Pupae	69.2 ± 3.19 c

***Means in the column and attachment with the same letter did not differ significantly (ANOVA test at a significant level of 5%)**

These results agree with[13]. which showed that the first and second larvae were more predatory than larvae This study found that the environmental conditions had a significant effect in the daily predation and was very low for the pupae compared to the larvae. The pupae are kept away from the predators . These results agree with study [14] with a laboratory study that *Cypister tripunctatus* larvae in the second and third phases showed a high predatory ability to all the roles of *C.pipines* mosquitoes. This study agree with the study conducted in a laboratory study and field similar to the current study by [15]

which proved that *Agabus spp* beetles showed a high predatory ability against different larval of *C.pipine*s showed an inverse correlation between the size of the predator and the predation process, small-sized predators showed more predisposition than predators of large size. The results of the [16] study on the submersible aquatic beetles *Eretes stictus* and *Dineutes aereus* correspond to the results of the present study, which showed that the first and second phase of *Culex perexiguus* mosquitoes is one of the most larval stages of prey.

IV. Functional response

Functional response of predator *D.aereus*, for different densities of the mosquitoes *C.pipiens*

The functional response curve for the second stage of the predator *D.aereus* (Fig. 2) indicated an increase in the number of larvae consumed at a decreasing rate with increasing numerical density as the response curve gradually decreases until stright.The results of the statistical analysis showed that the number of prey consumed by predator increases with the density of these prey in the area around the predator table(3). The predator *D.aereus* the 20 consumed from larvae of the second stage at an average of 17.20 larva / day, and with the predator density increasing around the predator 40, 60, 80, 100 larvae / day The number of larvae consumed by the predator increased by 34.20 , 53.20 , 66.4 ,71.00 larvae / day, respectively. When there were 120 larvae, the predation decreased to a rate of 70.4 larvae / day.The results of the study of the time taken by the predator in the search for the second stage larvae of *C.pipine*s showed that with the increase in prey density from 20 to 120 larva / predator / day, the gradua decrease in the time of prey was from 6.00 to 3.52 hours.

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Table 3:Average consumption of predator female *D. aereus*, for different densities of mosquitoes *C. pipiens* with in 24 hours

Number of larvae	Larvae stage	Mean number of preyied larvae ± standard deviation	Predator search time for prey / hour
20	Second	17.20 ± 1.75 e	6.00
40		34.40± 2.82 d	5.81
60		53.20± 3.24 bc	5.58
80		66.4 ± 4.51 ab	4.81
100		71.0± 5.63 a	4.29
120		70.4± 8.87 ab	3.52

***Means in the column and attachment with the same letter did not differ significantly (ANOVA test at a significant level of 5%)**

The functional response curve for the fourth stage of the *D.aereus* (Fig. 3) indicated an increase in the number of larvae consumed at a decreasing rate with increasing numerical density as the response curve gradually decreases until stright The results of the statistical analysis show that the number of prey consumed by predator increases with the density of these prey in the area around the predator .The table(4) showed that the number of larvae consumed by the predator was increased with the larvae density of the larvae in the area surrounding the predator. The predator *D.aereus* had 20 larvae of the fourth stage larvae with an average of 13.40 larvae / day, The prey of densities 40, 60, 80, 100 larvae ,The number of larvae consumed by the predator increased by 24.00, 39.60, 46.2, 49.6 larva / day, respectively. When there were 120 larvae, the predation decreased to a rate of 46.5 larvae / day . The results of the study and time taken by the predator in the search for the prey of the fourth stage larvae of *C.pipiens* that with the increase of the density of prey from the rate of 20 to 120 larvae / predator / day led to a gradual decrease in the time of search for prey from 5.59 to 2.61 hours.

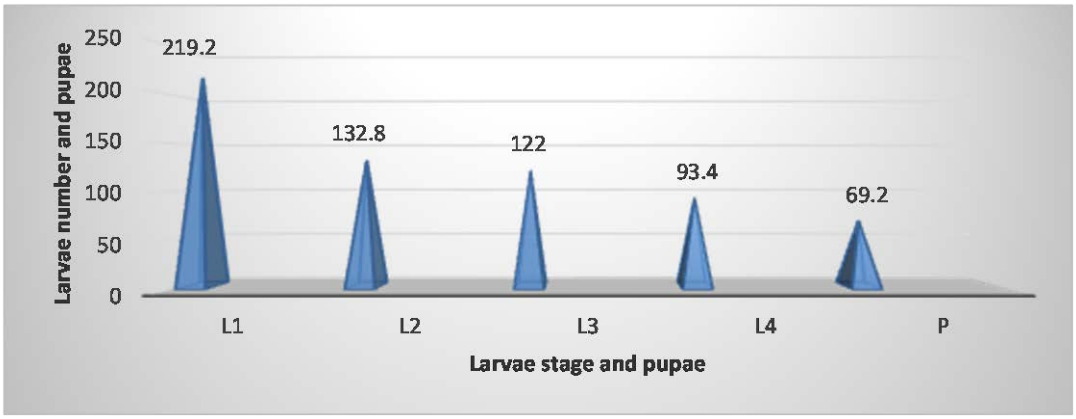
Table 4: Average consumption of predatore female *D. Aereus*, for different densities of mosquitoes *C. Pipiens* within 24 .

Number of larvae	Larvae stage	Mean number of preyied larvae ± standard deviation	Predator search time for prey / hour
20	Fourth stage	13.40± 1.82 e	5.59
40		24.20± 1.98 de	4.41
60		39.60± 2.53 cd	3.79
80		46.2± 3.59 bc	3.09
100		49.6± 2.64 a	2.89
120		46.5± 2.52 ab	2.61

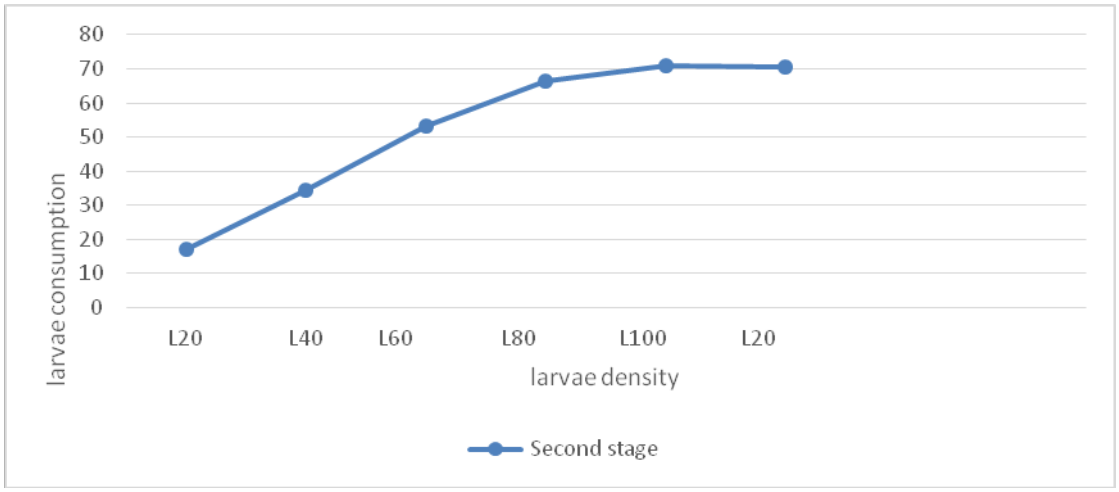
***Means in the column and attachment with the same letter did not differ significantly (ANOVA test at a significant level of 5%)**

The above results indicate that predator *D.aereus* follows the second type II [7] , the convex shape, as predator capacity increases with increased prey density and then reaches limit The increase in predatory force is dependent upon increased. Number of second and fourth-stage insects *of C. pipiens* consumed by predator *D.aereus* increases exponentially by increasing the density of mosquito larvae but decreasing rapidly as mosquito larvae consumed at the first density are between 20-80 higher than the higher densities, making the curved shape fit into the shape of the pattern The second type II of the functional response that preys by of different densities of prey, which is determined by the saturation of the predator and the processing time, is an inversely dependent [17]. The present study results are consistent with[18] in terms of the form of functional response or so-called mortality rate, despite the different type of predators used for the current experiments and the type of prey and its development. It is noted that the prey consumes the entire body of the prey in the low densities of the prey in the second and fourth stages to the larvae of mosquitoes, while in high densities we see the consumption of all the prey or part of the prey, leaving the legs, head, and part of the thorax region. This explains the increase in the number of larvae consumed partially or completely by the predator, apparently reaching a certain level kill or consume any larger numbers, which explains the level of the curve at densities between 120 - 80 larva / predator / day .The efficiency of any predator can be varied depending on the type of prey and prey size, as well as other factors such as surronding temperature, relative humidity, predator density, area

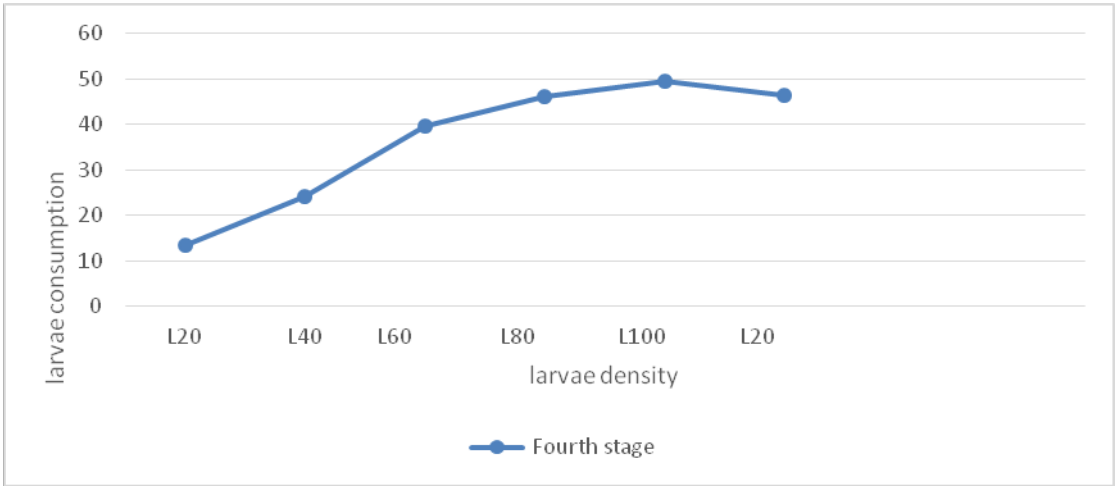
of research, photovoltaic period, and other species of predators and parasites [19]. This study is in agreement with [20] finding that *Eretes griseus* water beetles followed the second model of funtional respone response and reached the highest predisposition rate of 65.21 larvae / day *of Culex Quinquefasciatus* at 96 larval densities . This study is agree with [21] To demonstrate the functional response of aquatic beetles *Eretes griseus, suturalis Rantus, Hydaticus gramicus* in the larvae of *Culex tritaeniorhynchus* and *Aedes albopictus* mosquitoes, *E. griseus, R.suturalis, H. gramicus* showed functional response of type II at different phase densities of the Fourth instar of mosquitoes *Culex tritaeniorhynchus* and mosquitoes *Aedes albopic*. . .



L1:First larval stage L2: Second larval stage L3: Third larval stage L4: Fourth stage pupae
Figur 1. Mean average efficiency of *D.aereus* on *C.pipiens* mosquitoes under laboratory conditions



Figur2. Functional respone of *D.aereus* for different densities of second-stage larvae of mosquitoes *C. pipiens*



Figur3. Functional respone of *D.aereus* for different densities of fourth-stage larvae of mosquitoes *C. pipiens*

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