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Growth Rate of the Top Shell *Tectus dentatus* (Forskål, 1775) Under Laboratory Conditions, 1- Effect of Density

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ABSTRACT
To study the effect of stocking density on the growth rate and survival of the top shell *Tectus dentatus* in captivity, four size groups of the top shell were selected. This trial started from 15th October 2010 and ended in 15th February 2011. The stocking densities were adjusted depending on the initial size of the animal. *Tectus* growth rates at different stocking densities in tanks showed that appropriate densities were 50 ind m^{-3} for specimens with mean maximal basal diameter (MBD) 25.08 mm (± 2.28) (SD) and mean body weight 18.12 g (± 1.11), 25 ind m^{-3} for specimens with (MBD) 35.10 mm (± 1. 23) and mean body weight 31.21 g (±1.85), 20 ind m^{-3} for specimens with (MBD) 46.24 mm (± 1.78) and mean body weight 46.09 g (± 4.22) and 10 ind m^{-3} for specimens with (MBD) 54.24 mm (± 2.15) and mean body weight 87.20 g (±7.85).

1. INTRODUCTION
Tectus dentatus (Forskål, 1775) is a marine gastropod that belongs to family Trochidae (Hickman and McLean 1990), which inhabits the intertidal and shallow subtidal zones. Its preferred habitat is the moderately exposed coral reef shore (McGowan, 1956; Gail, 1957; Smith, 1979). *Trochus* spp. are gonochoric, without any external sexual dimorphism. (Amirthalingam, 1932).

Eisawy (1970), in the Red Sea, showed that sexes of *T. dentatus* are separate without external sexual differences and the spawning season extends from April to July, at a water temperature ranging between 20°C and 30°C. Eltayeb (1999) found that the top shell *T. dentatus* in the Sudanese Red Sea Coast mainly dominates the reefs edge and reef crest, with depths not greater than 5 m. Its distribution is affected by different factors such as algal growth and reef topography. Gaha (2008) studied the distribution and abundance of *T. dentatus* in Rabigh area on the Red Sea, in addition to management for the shell fisheries in the area.

T. dentatus is the largest and most important member of the family Trochidae in the Red Sea. Its meat is valued as food the shell is the most valuable part of the trochus.

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It is used for many purposes as souvenirs, buttons manufacture and is therefore of commercial importance e.g. manufacture of dental fillings, wood furniture inlays, in cosmetics and paint. (King, 2001; Bouchet and Bour, 1980; Nash, 1993; Eisawy, 1970).

In Egypt, *T. dentatus* has been exploited for human consumption, and shells are marketed as souvenirs (the current market price is about 7,000–10,000 Egyptian pounds per ton.

This article is the first of a series focusing on this gastropod. The aim of this study is to investigate the growth rate of *T. dentatus* in captivity by rearing the animal at different densities, which can provide the basis for top shell aquaculture in Egypt.

2. MATERIAL AND METHODS

The experimental specimens were collected through snorkeling or SCUBA diving by hands, about 2 to 6 meters depth, from Gemsha bay (27° 39` N: 33° 29` E) and transferred to the laboratory of the National Institute of Oceanography and Fisheries in Hurghada. These specimens were cleaned carefully by a scrubbing brush and divided into 4 size groups according to maximum basal diameter (MBD) in millimeters, using a vernier calliper (Size group 1, < 30 mm; Size group 2, < 40 mm; Size group 3, < 50 mm and Size group 4,< 60 mm). Data concerned with the survivors, (MBD) in millimeters and total weight in grams were recorded bimonthly.

T. dentatus were reared in 1.0 m^3 cylindrical fiberglass tanks. Seaweed and algae attached to or growing on dead corals or rocks were used as natural food. The dead coral and rocks were collected from adjacent areas and placed inside the culture tanks to cover about 50% -75% of the bottom area. Food was changed and tanks cleaned four times a month. This trial started from 15th October 2010 and ended in 15th February 2011. Data were analyzed by the statistical program SPSS (v 18) along with analysis of variance (One-Way ANOVA). Standard deviations (SD) are given in parentheses.

2.1 Experiment 1

The three stocking densities tested were 50 ind m^{-3}, 75 ind m^{-3} and 100 ind m^{-3}. The initial mean maximal basal diameters (MBD) were 25.08 mm, (± 2.28), 25.27 mm (± 2.15) and 25.31 mm (± 1.96) and mean body weights were 18.21g (± 1.11), 18.52 g (± 1.41) and 18.78 g (± 1.24) respectively (Tables 1& 2).

Table 1: Mean basal diameter for each size group of *T. dentatus* reared at different densities (± the standard deviation) from 15 October 2010 to 15 February 2011.

Month	Size group 1			Size group 2			Size group 3			Size group 4		
	50 Ind.	75 Ind.	100 Ind.	25 Ind.	50 Ind.	75 Ind.	20 Ind.	30 Ind.	40 Ind.	10 Ind.	20 Ind.	30 Ind.
15-Oct.	25.08 ± 2.28	25.27 ± 2.15	25.31 ± 1.96	35.10 ± 1.23	35.22 ± 1.62	35.38 ± 1.88	46.24 ± 1.78	46.55 ± 2.24	46.75 ± 2.84	54.24 ± 2.15	54.38 ± 1.47	54.64 ± 1.88
01-Nov.	25.52 ± 2.37	25.49 ± 2.32	25.48 ± 2.21	35.42 ± 1.51	35.40 ± 1.85	35.48 ± 2.23	46.95 ± 1.92	46.87 ± 2.41	46.80 ± 3.25	54.71 ± 2.32	54.69 ± 1.61	54.65 ± 2.32
15-Nov.	26.44 ± 2.72	26.35 ± 3.11	25.73 ± 2.33	35.80 ± 1.69	35.74 ± 2.03	35.62 ± 2.41	47.18 ± 2.02	47.03 ± 2.62	46.92 ± 3.33	54.78 ± 2.55	54.74 ± 1.85	54.70 ± 2.65
01-Dec.	28.85 ± 2.66	28.00 ± 2.54	26.70 ± 2.51	36.48 ± 1.55	36.29 ± 2.21	36.02 ± 2.61	47.46 ± 2.29	47.23 ± 2.71	47.01 ± 3.58	54.92 ± 2.81	54.86 ± 1.98	54.75 ± 2.85
15-Dec.	30.45 ± 2.91	30.00 ± 2.78	27.70 ± 2.63	37.52 ± 1.38	36.98 ± 2.42	36.51 ± 2.74	47.83 ± 2.35	47.59 ± 2.86	47.23 ± 3.75	55.05 ± 2.89	54.95 ± 2.35	54.85 ± 3.32
01-Jan.	33.56 ± 1.88	32.78 ± 2.86	29.00 ± 2.73	38.74 ± 1.88	38.41 ± 2.64	37.19 ± 2.78	48.32 ± 2.44	47.98 ± 2.93	47.50 ± 4.20	55.26 ± 3.45	55.11 ± 3.14	54.93 ± 3.47
15-Jan.	36.20 ± 2.86	34.90 ± 3.19	30.00 ± 3.25	40.22 ± 1.79	39.78 ± 2.55	38.09 ± 2.96	49.07 ± 2.75	48.58 ± 3.26	47.76 ± 4.35	55.56 ± 3.66	55.30 ± 2.74	55.06 ± 3.56
01-Feb.	39.00 ± 2.96	37.50 ± 3.41	31.10 ± 3.36	42.30 ± 2.02	41.78 ± 2.49	38.93 ± 3.11	49.77 ± 2.91	49.26 ± 3.46	48.15 ± 4.62	56.11 ± 3.78	55.68 ± 2.78	55.32 ± 3.22
15-Feb.	41.80 ± 3.14	40.00 ± 3.62	32.30 ± 3.52	44.29 ± 2.13	43.68 ± 2.81	40.68 ± 3.30	50.45 ± 2.98	49.92 ± 3.82	48.71 ± 4.78	56.78 ± 3.92	56.24 ± 3.25	55.87 ± 4.05

Table 2: Mean total weight for each size group of *T. dentatus* reared at different densities (± the standard deviation) from 15 October 2010 to 15 February 2011.

Month	Size group 1			Size group 2			Size group 3			Size group 4		
	50 Ind.	75 Ind.	100 Ind.	25 Ind.	50 Ind.	75 Ind.	20 Ind.	30 Ind.	40 Ind.	10 Ind.	20 Ind.	30 Ind.
	18.21 ±	18.52 ±	18.78 ±	31.21 ±	31.56 ±	31.78 ±	46.09 ±	46.22 ±	46.38 ±	87.20 ±	87.14 ±	87.08 ±
15-Oct.	1.11	1.41	1.24	1.85	2.21	2.47	4.22	5.21	5.39	7.85	8.24	7.69
	19.23 ±	19.15 ±	19.11 ±	31.83 ±	31.71 ±	31.84 ±	47.09 ±	46.81 ±	46.61 ±	87.33 ±	87.23 ±	87.20 ±
01-Nov.	1.96	2.52	2.19	2.36	2.75	3.11	4.62	5.23	6.25	7.65	8.44	8.22
	20.35 ±	20.01 ±	19.47 ±	32.69 ±	32.22 ±	31.98 ±	47.83 ±	47.45 ±	46.93 ±	87.66 ±	87.45 ±	87.29 ±
15-Nov.	2.15	2.33	2.35	2.55	2.78	3.65	4.24	5.56	5.65	8.01	8.69	8.45
	21.98 ±	21.56 ±	20.35 ±	33.90 ±	32.92 ±	32.22 ±	48.67 ±	48.22 ±	47.51 ±	88.12 ±	87.73 ±	87.41 ±
01-Dec.	3.09	2.75	2.54	2.78	2.93	3.87	5.24	5.98	5.77	8.32	8.38	8.71
	23.40 ±	23.05 ±	21.30 ±	35.56 ±	34.32 ±	32.63 ±	49.63 ±	49.00 ±	47.96 ±	88.91 ±	88.12 ±	87.60 ±
15-Dec.	3.56	2.86	3.15	2.92	3.23	4.22	5.41	6.22	6.33	8.52	9.05	8.90
	25.80 ±	25.00 ±	22.30 ±	37.32 ±	35.73 ±	33.32 ±	51.24 ±	50.34 ±	48.60 ±	89.90 ±	88.78 ±	87.88 ±
01-Jan.	3.42	3.21	3.32	3.14	3.55	3.98	5.67	6.19	6.57	8.78	9.16	9.21
	27.42 ±	26.75 ±	23.25 ±	39.76 ±	37.95 ±	34.29 ±	52.92 ±	51.90 ±	49.50 ±	91.38 ±	90.10 ±	88.29 ±
15-Jan.	2.83	3.33	3.39	3.23	3.81	4.18	6.22	6.74	6.68	9.36	9.44	9.08
	30.56 ±	29.69 ±	24.48 ±	42.29 ±	40.75 ±	35.76 ±	54.59 ±	53.28 ±	50.53 ±	93.79 ±	91.65 ±	89.20 ±
01-Feb.	3.65	3.49	3.75	3.54	4.09	4.38	6.19	6.69	6.88	9.44	9.71	9.07
	34.56 ±	32.73 ±	26.00 ±	46.49 ±	44.71 ±	38.10 ±	56.65 ±	55.23 ±	52.15 ±	96.45 ±	94.25 ±	91.12 ±
15-Feb.	3.74	3.66	3.82	3.68	3.68	4.86	6.32	7.08	6.96	9.74	9.82	9.44

Experiment 2

The three stocking densities tested were 25 ind m^{-3}, 50 ind m^{-3} and 75 ind m^{-3}. The initial means (MBD) were 35.10 mm (± 1.23), 35.22 mm (± 1.62) and 35.38 mm (± 1.88) and mean body weights were 31.21g (± 1.85), 31.56 g (± 2.21) and 31.78 g (± 2.47) respectively. Tables (1&2).

Experiment 3

The three stocking densities tested were 20 ind m^{-3}, 30 ind m^{-3} and 40 ind m^{-3}. The initial means (MBD) were 46.24 mm (± 1.78), 46.55 mm (± 2.24) and 46.75 mm (± 2.84) and mean body weights were 46.09 g (± 4.22), 46.22 g (± 5.21) and 46.38 g (± 5.39) respectively. Tables (1&2).

Experiment 4

The three stoking densities tested were 10 ind m^{-3}, 20 ind m^{-3} and 30 ind m^{-3}. The initial means (MBD) were 54.24 mm (± 2.15), 54.38 mm (± 1.47) and 54.64 mm (± 1.88) and mean body weights were 87.20 g (± 7.85), 87.14 g (± 8.24) and 87.08 g (± 7.69) respectively. Tables (1&2).

Generally, Table (3) summarize the initial measurements of both MBD and mean total weight (MTW) of *T. dentatus* at different stock densities.

Table 3: Summarize the initial measurements for both MBD and MTW ± S.D. of *T. dentatus* reared at different stocking densities.

Size group	Initial mean Body size	Stocking densities used		
Size group 1	ind m^{-3}	50	75	100
	MBD	25.08±2.28	25.27±2.15	25.31±1.96
	MTW	18.12±1.11	18.52±1.41	18.78±1.24
Size group 2	ind m^{-3}	25	50	75
	MBD	35.10±1.23	35.22±1.62	35.38±1.88
	MTW	31.21±1.85	31.56±2.21	31.78±2.47
Size group 3	ind m^{-3}	20	30	40
	MBD	46.24±1.78	46.55±2.24	46.75±2.84
	MTW	46.09±4.22	46.22±5.21	46.38±5.39
Size group 4	ind m^{-3}	10	20	30
	MBD	54.24±2.15	54.38±1.47	54.64±1.88
	MTW	87.20±7.85	87.14±8.24	87.08±7.69

3. RESULTS

3.1 Experiment 1

There were no significant difference between growth rates (in length and weight) of *Tectus* reared at a density of 50 ind m^{-3} and those of 75 ind m^{-3} as shown in Figs. (1 & 2) but those in both treatments grew faster than that reared at a density of 100 ind m^{-3}. The final recorded MBD were 41.80 mm (± 3.14), 40.00 mm (± 3.62) and 32.30 mm (± 3.52) as shown in tables (1&2) and mean body weights were 34.56 g (± 3.74), 32.73 g (± 3.66) and 26.00 g (± 3.82) at all densities respectively. (ANOVA, $p < 0.001$). The survival rate at 50 ind m^{-3} was 100% and it was 90% at 75 ind m^{-3} but it was 65% at a density of 100 ind m^{-3}. Standard deviations are given in parentheses.

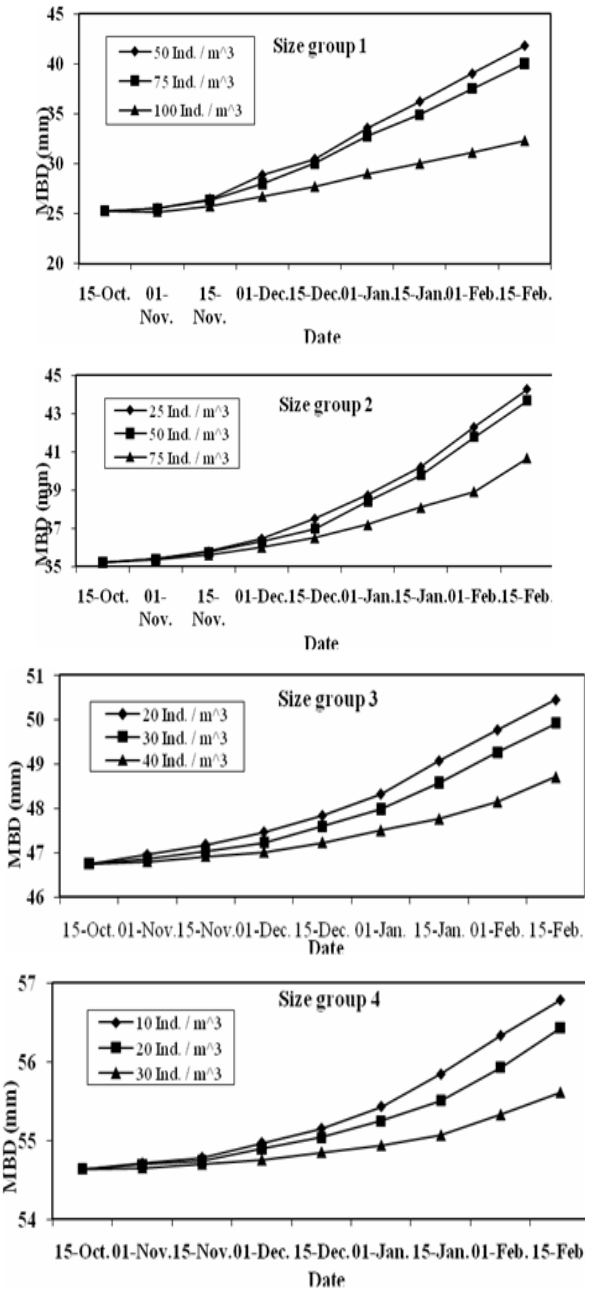

Fig.1: Mean basal diameter of *T. dentatus* reared at different densities

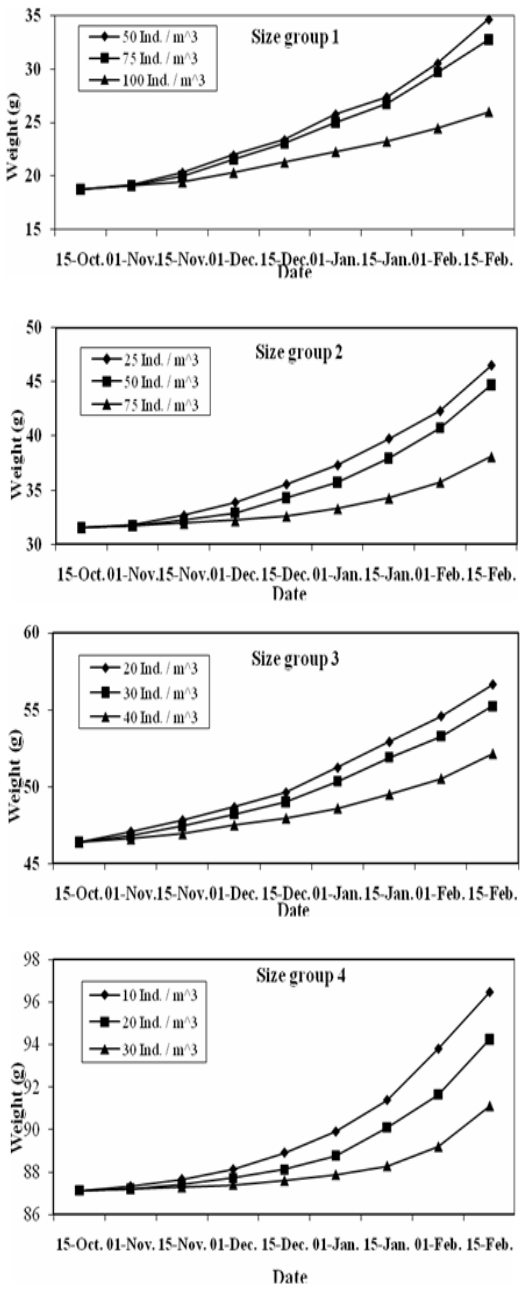

Fig. 2: Mean total weight of *T. dentatus* reared at different densities.

3.2 Experiment 2

There were no significant difference between growth rates (in length and weight) of *Tectus* reared at a density of 25 ind m^{-3} and those of 50 ind m^{-3} as shown in Figs. (1 & 2) but individuals in both treatments grew faster than those reared at a density of 75 ind m^{-3}. The final MBD were 44.29 mm (± 2.13), 43.68 mm (± 2.81) and 40.68 mm (± 3.30) as shown in Tables (1&2) and mean body weights were 46.49 g (± 3.68), 44.71g (± 3.68) and 38.10 g (± 4.86) respectively. (ANOVA, $p<0.05$). Furthermore, the survival rates were 100%, 90% and 60 % at a density of 25, 50 and 75 ind m^{-3} respectively.

3.3 Experiment 3

There were no significant difference between growth rates of *Tectus* reared at a density of 20 ind m^{-3} and those of 30 ind m^{-3} as shown in Figs. (1 & 2) but those in both treatments grew faster than that reared at a density of 40 ind m^{-3}. The final MBD were 50.45 mm (± 2.98), 49.92 mm (± 3.82) and 48.71 mm (± 4.78) as shown in tables (1&2) and mean body weights were 56.65 g (± 6.32), 55.23 g (± 7.08) and 52.15 g (± 6.96) respectively. (ANOVA, $p<0.01$). The survival rates were 95%, 80% and 70 % at a density of 20, 30 and 40 ind m^{-3} respectively.

3.4 Experiment 4

There were significant difference between growth rates of *Tectus* reared at the three densities (10 ind m^{-3}, 20 ind m^{-3} and 30 ind m^{-3}) as shown in Figs. (1 & 2). (ANOVA, $p<0.01$). The final MBD were 56.78 mm (± 3.92), 56.24 mm (± 3.25) and 55.87 mm (± 4.05) as shown in tables (1&2) and the respective mean body weights were 96.45 g (± 9.74), 94.25 g (± 9.82) and 91.12 g (± 9.44). The survival rates were 100%, 70% and 60% respectively.

Generally, the growth was inversely dependent on the stocking density of *T. dentatus* Tab. (4) and Figs. (3&4).

Table 4: Growth rate $month^{-1}$ in MBD and in weight for *T. dentatus* at different stocking densities

Size groups	Density ($ind.m^{-3}$)	Growth rate $month^{-1}$ MBD (mm)	Weight (g)
size group 1	50	4.18	4.09
(20-30) mm	75	3.68	3.55
	100	1.75	1.80
size group 2	25	2.30	3.82
(30-40) mm	50	2.12	3.29
	75	1.33	1.58
size group 3	20	1.05	2.64
(40-50) mm	30	0.84	2.25
	40	0.49	1.44
size group 4	10	0.64	2.31
(50-60) mm	20	0.47	1.78
	30	0.31	1.01

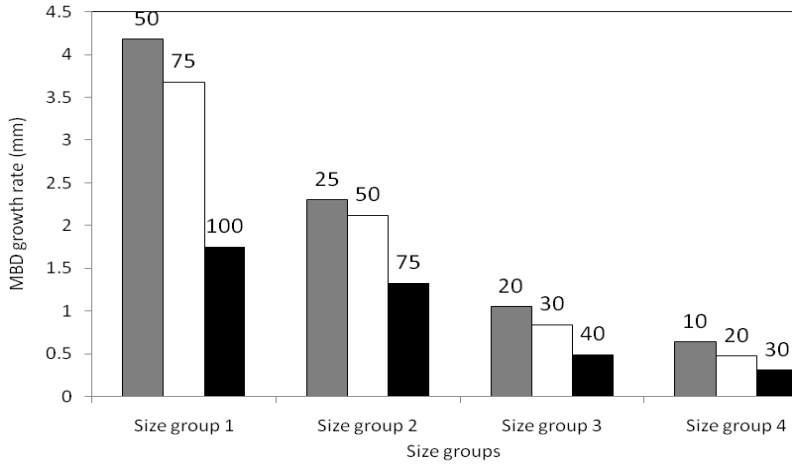

Fig (3) Growth rate in MBD for each size group in different densites of *T. dentatus*

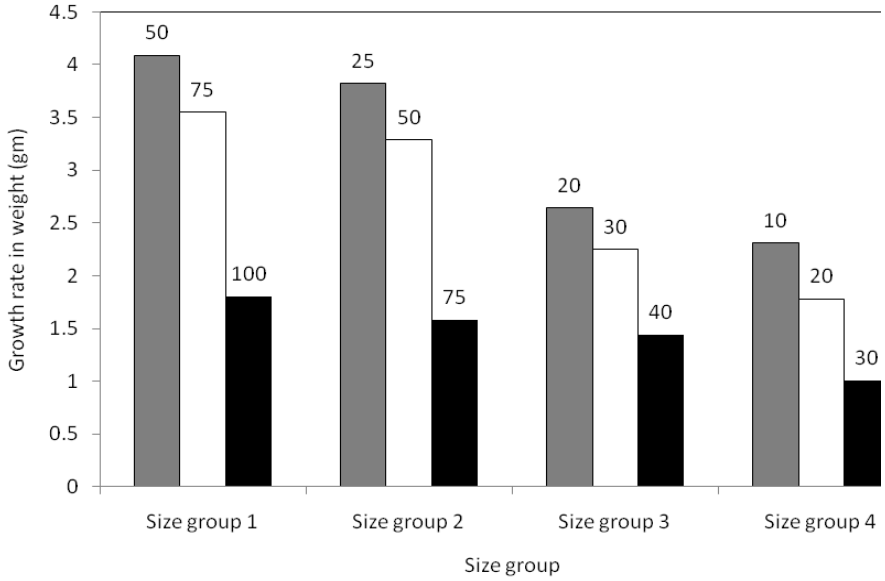

Fig (4) Growth rate in weight for each size group in different densities of *T. dentatus*

4. DISCUSSION

Growth occurs when a part of assimilated food or energy is retained and incorporated into the biomass of the organism (Kideys and Hartnoll, 1991 and Ilano *et al*., 2004).

Effects of population density and limitation of food resources seem to be more probable causes for growth rate variations, as demonstrated for many intertidal gastropods (Hylleberg and Christensen, 1978; Underwood, 1978 & 1979).

This study showed that the growth rate of *Tectus* depends on culture densities; which depends on the size of animals. So, on increasing of *Tectus* size, its densities should be decreased i.e. the animals grew well and the survival rate was higher in tanks with lower densities proportion with size groups that may be due to the competition of food.

It is recommended that culture stocking densities be adjusted depending on the initial size of the *Tectus*. At MBD of 20-30 mm, *Tectus* can be cultured at a density up to 50 ind m^3 (where monthly growth rate was 4.18 mm and survival rate was 90%). In case of 75 ind m^3, the monthly growth rate was 3.68 mm and survival rate was 90%, while at a density 100 ind m^3, the monthly growth rate was 1.75 mm and survival rate was 65%.

When *Tectus* reach 30-40 mm, the density should be reduced to less than 25 ind m^3 (where monthly growth rate was 2.30 mm and survival rate was 100%) compared with 2.12 mm $month^{-1}$ and 1.33 mm $month^{-1}$ for rearing tanks with *Tectus* densities of 50 ind m^3 and 75 ind m^3 respectively) (Tabs. 1 and 2).

The density should be reduced to less than 20 ind m^3 when *Tectus* individuals reach 40-50 mm (where monthly growth rate was 1.05 mm and survival rate was 96%, compared with 0.84 mm $month^{-1}$ and 0.49mm $month^{-1}$ for rearing tanks with *Tectus* densities of 30 ind m^3 and 40 ind m^3 respectively).

In case of *Tectus* size of 50-60 mm, the density should be declined to 10 ind m^3 (growth rate was 0.64 mm $month^{-1}$ and survival rate was 99%, compared with 0.47 mm $month^{-1}$ and 0.31 mm $month^{-1}$ for rearing tanks with *Tectus* densities of 20 ind

m^3 and 30 ind m^3 respectively) (Tabs.1 and 2).

The obtained results show, that small *Tectus* grew faster than larger ones under the same conditions. These results agree with that obtained by Do *et al*., (2007) for *Trochus.*

Most previous studies on *Trochidae* showed more or less similar results to that obtained in the persent study.

Clarke *et al.*, (2003) suggested that there was a density-dependent effect on the growth of *Trochus*: the mean size of individuals stocked at 15 per m^2 cage was significantly greater than those held at 30 per m^2 cage at the end of the experiment. Evans *et al.* (2011) showed that *Gibbula nirosa* reached 9 mm MBD in less than one year. Do *et al.* (2007) proved that *T. niloticus* growth rates at different culture densities in cages (1 x 1 x 0.6 m) while the appropriate densities were <50 ind m^{-2} for individuals measuring 25-40 mm MBD and <10 ind m^{-2} for individuals of 40-50 mm MBD and down to 4–7 ind m^{-2} for *Trochus* larger than 50 mm MBD. Clarke *et al.* (2003) reported that although the mean growth rates for *Trochus* with a mean size of 5.61 mm MBD in concrete tanks (4.5 mm $month^{-1}$) were not as great as those for concrete raceways reported by Heslinga (1981) (5.4 mm $month^{-1}$), they also exceeded those reported from other fiber-glass tanks (3.06 mm $month^{-1}$) by Dwiono et al. (1997).

Purcell *et al.* (2004) determined the growth rate of >2.3 mm $month^{-1}$ for *T. niloticus* at culture densities of 30 ind m^{-2} with a mean size of 50-60 mm MBD, while Lee *et al.* (1998) showed that such growth rate at culture densities up to 30 ind m^{-2} with a mean size of 16-25 mm MBD in cages was (2.1-3.9) mm $month^{-1}$. Similarly, Amos and Purcell (2003) showed that growth rate of the same species was 2.6 mm $month^{-1}$ for culture densities up to 30 ind m^{-2} with a mean size of 15-30 mm MBD.

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