RESULTS AND DISCUSSION

4. RESULTS AND DISCUSSION

4.1. First experiment:

4.1.1. Effect of spawning month, dietary protein content and tank protection on fry number/tank:

Averages of fry number produced per tank as affected by month, dietary protein level and protection method were found to be 6462 and 19082 during the two months April and May, 10719 and 14824 for the two dietary protein levels, 25 and 35% and 16428 and 9115 fry/tank for the covered and uncovered tanks, respectively (Table 7). Analysis of variance (Table 8) indicated that, spawning month, dietary protein content and tank protection significantly ($P<0.001$) affected the fry number produced per tank.

As shown in Table (7) fry number produced/tank during May was significantly higher than produced in April and this may be due to increasing in water temperature during May compared to water temperature in April. Reproduction of tilapia will cease to occur at temperatures below 22°C **(Chervinski, 1982)**. Similarly, tank protection during the two months (April and May) increased significantly fry production and this may be due to the suitability of water temperature by covering fish tanks (27.39 and 26.95°C). **Sidiqui *et al.*, (1998)** found that, in Saudi Arabia, the maximum spawning activity of Nile tilapia, *O. niloticus* was recorded between May and August and thereafter, the spawning frequency gradually decreased with very low activity in November.

Table (7): Least square means and standard error for the effect of month, dietary protein level and protection method on fry production of Nile tilapia.

Variable	No.	Fry production / pond	Temperature (°C)
Month (M)			
April (M1)	16	6462±662 b	
May (M2)	16	19082±662 a	
Protein level (P)			
25% (P1)	16	10719±662 b	
35% (P2)	16	14824±662 a	
Protection method (C)			
Covered (C1)	16	16428±662 a	
Uncovered (C2)	16	9115±662 b	
M × P			
M1 × P1	8	6917±936 c	
M1 × P2	8	6007±936 c	
M2 × P1	8	14522±936 b	
M2 × P2	8	23642±936 a	
M × C			
M1 × C1	8	9657±936 c	
M1 × C2	8	3267±936 d	
M2 × C1	8	23200±936 a	
M2 × C2	8	14963±936 b	
P × C			
P1 × C1	8	13200±936 b	
P1 × C2	8	8238±936 d	
P2 × C1	8	19657±936 a	
P2 × C2	8	9992±936 c	
M × P × C			
M1 × P1 × C1	4	10834±792 d	27.39
M1 × P1 × C2	4	3000±792 f	21.89
M1 × P2 × C1	4	8480±792 e	27.39
M1 × P2 × C2	4	3533±792 f	21.89
M2 × P1 × C1	4	15567±792 bc	26.95
M2 × P1 × C2	4	13476±792 c	23.75
M2 × P2 × C1	4	30833±792 a	26.95
M2 × P2 × C2	4	16450±792 b	23.75

+ Means followed by the same letter in each column are not significantly different.

Table (8): Analysis of variance for the effect of month, dietary protein level and protection method on fry production of Nile tilapia.

S.O.V	df	F-ratio
Month (M)	1	508.44***
Protein (P)	1	53.79***
Protection (C)	1	170.77***
M × P	1	80.30***
M × C	1	2.72
P × C	1	17.65***
M × P × C	1	45.98***
Remainder df	24	
Remainder MS		25058361

*** P<0.001

Water temperature is one of the most potent environmental factors influencing the developmental rate of fish eggs and fry (**Herzig and Winkler, 1986**). Generally, low rearing temperatures retard and high temperatures accelerate development. The habitat temperature and the temperature range over which eggs will develop and hatch normally varies between species, each specie having an optimal range for maximal developmental success depending on its ecology and life history.

For *Oreochromis* species an understanding of these thermal tolerance ranges is of considerable ecological as well as aquacultural interest, especially as the distribution of these species is now much extended outside their natural range. For example, **Denzer (1968)** reported a range of 20°C between winter and summer water temperatures of thermal effluents used to rear *O. niloticus* (L.). In open water bodies, which may be at altitude, species such as *O. niloticus* may be subjected to large seasonal and diurnal fluctuations. In the shallow water of tropical and equatorial lakes, diurnal changes may be in excess of 15°C (**Caulton, 1982**).

Under hatchery conditions, however, it may be possible to control and maintain water temperatures within a narrow thermal range for optimal embryo and fry development. This would be of considerable importance since the various stages of embryonic development may have different thermal tolerance ranges and optimal temperature requirements (**Ehrlich and Muszynski, 1981**). Furthermore, these authors have shown that the earlier embryonic stages are more susceptible to thermal stress than advanced stages.

With respect to the effect of dietary protein content on fry production of Nile tilapia, *Oreochromis niloticus*, results of Table (7) indicated that fry number/tank was increased from 10719 to 14824 as dietary protein content increased from 25 to 35%, respectively.

Nutrition of broodstock fish is usually reflect in their reproduction efficiency. The interaction between nutrition and reproduction of tilapia has recently attracted the attention of investigators (**DeSilva and Radampola, 1990 and El-Sayed** ***et al.,***

2003), who have studied the relationship between dietary protein and spawning efficiency.

Dietary protein has been found to influence seed production in tilapia. An increase in egg production with an increase in dietary protein levels has been reported for Nile tilapia, *Oreochromis niloticus* **(Santiago, *et al.*, 1985)** and Taiwanese red tilapia **(Chang *et al.*, 1988)**

Santiago *et al.* (1985) reported that the best growth of *Oreochromis niloticus* breeders and the highest fry production were obtained at 40% dietary protein, while lower protein levels resulted in reduced fry production. Similar results were obtained with 2 to 3 years old of *Oreochromis mossambicus* × *Oreochromis niloticus*. **Chang *et al.*, (1988)** found that a diet containing 44% protein (eel diet) produced the highest number of fry, while tilapia feed (24% protein) and trash fish flesh (22% protein) resulted in significantly lower fry production. In the same trend, **Wee and Tuan (1988)** formulated five diets to give dietary protein levels ranging from 20% to 50% with 7.5% increments and they found that, tilapia fish fed the low and medium levels of dietary protein (20, 27.7 and 35%) had higher fecundity (6.4, 7.0, 6.7 eggs/g, respectively), moreover, the former groups had smaller eggs and later group spawned earlier but less often also the former groups spawned later but more frequently. **Gunasekera *et al.*, (1995)** concluded that 32% protein seems to be adequate for tilapia broodfish. In another study, **Gunasekera *et al.*, (1996 b)** investigated the effect of different dietary protein levels (10, 20 or 35%) on reproductive performance of Nile tilapia *Oreochromis niloticus* and they found that, females fed the 10% CP diet did not produced fertilized eggs while fertilization rate of eggs spawned by females fed the 35% CP diet was generally higher than that from females maintained on the 20% CP diet, also they found that, hatchability of eggs from females fed the 35% CP diet was significantly higher than those from females fed the 20% CP diet. In another study, **Gunaskra et al., (1996 a)** found that Nile tilapia females fed 20 or 35% protein diets produced higher number of eggs per spawn than those fed 10% but relative fecundity and egg size did not differ significantly ($P<0.05$) between treatments (10, 20 and 35% CP diets).

In the study of **Siddiqui *et al.,* (1998),** Nile tilapia fed experimental diets contained increasing levels of dietary protein (25, 30, 35, 40 and 45%) showed that, fish received 45% dietary protein spawned more frequently than fish received 25% dietary protein and the total number of eggs produced per female was significantly higher for females fed 45% protein feed than females received 25% and 30% protein levels while relative fecundity had non clear trend and they concluded that the use of a 30% protein diet, based on both fish meal and other protein sources, is cost-effective for tilapia seed production under the local conditions.

In a recent study, **El-Sayed *et al.,* (2003)** studied the effect of increasing dietary protein levels (25, 30, 35 and 40%) on reproductive performance of Nile tilapia. They found that, the total number of spawnings per female and absolute fecundity were better in fish fed 40% protein and egg hatchability was linearly increased with increasing dietary protein level. The former studies recommended that high-protein diets must be given to tilapia breeders.

On the contrary, **DeSilva and Radampola (1990)** found that the number of spawning by females *Oreochromis niloticus* increased with increasing dietary protein level from 20 to 30%, then decreased with a further increase in protein level. In addition, the number of spawning repetition per female and the number of eggs per spawning episode decreased significantly with increasing dietary protein level. However, results were reported for *Sarotherodon melanotheran* by **Cisse (1988)** showed no significant differences in spawning frequency and mean number of eggs per spawn when the fish were fed diets containing 20 to 50% protein. The latter study postulated that 20 to 30% dietary protein is sufficient for tilapia broodstock, and it may be wasteful to use higher levels.

Generally, reproductive output is maintained at the expense of somatic growth. However, supply of inadequate protein for long periods results in slow ovarian recrudescence **(Gunasekera and Lam, 1997)**, prolonged intervals between spawnings **(Gunasekera *et al.*, 1996 a)** and a complete halt to reproduction. Broodfish should, therefore, be provided with optimum levels of protein in the diet from young age up to the egg producing stage.

The investigations of the dietary protein requirements of tilapia for maximum reproductive performance have produced variable results and no clear picture has emerged. The differences in results may be caused by variations in the experimental design with respect to the size of culture units, environmental conditions, hygiene, size and age of the fish, duration of the study and the quality of the feed. Manipulation of both dietary protein content and source of protein have affected egg production and egg quality.

The interaction between the former factors (spawning month, dietary protein content and tank protection) on fry production / tank (Table 7) indicated that during the second month of the experiment (May) covering broodstock tank and increasing the dietary protein content (from 25 to 35%) significantly ($P<0.001$) produced the highest (30833 fry / tank) of Nile tilapia and this may be due to improving in temperature conditions (26.95°C) required for producing the healthy fry of tilapia while the lowest fry production/tank (3533) was recorded for broodfish reared in uncovered tanks which received the higher dietary protein level in April.

4.1.2. Effect of spawning month, dietary protein content and tank protection on individual fry weight (g):

Averages of individual fry weight as affected by water temperature in month, dietary protein content and tank protection were found to be 0.025 and 0.016 g during the two months April and May, 0.021 and 0.019 g for the two dietary protein levels, 25 and 35% and 0.018 and 0.023 g for the covered and uncovered tanks, respectively (Table 9). Analysis of variance (Table 10) indicated that, spawning month and tank protection significantly ($P<0.001$ and $P<0.01$, respectively) affected individual fry weight produced while dietary protein content of the diets had no significant effect on fry weight.

The interaction between the studied factors affecting individual fry weight of Nile tilapia (Tables 9 and 10) indicated that the highest average individual fry weight (0.036 g / fry) was recorded for fish group raised in covered tanks and received the lower protein content during April. On the other hand, the lowest average individual fry weight (0.014 g/fry) was recorded for broodfish raised in an uncovered tanks and received the higher protein level (35%) in May and this may be due to the negative correlation between the two traits, fry weight and fry number.

In a recent study carried out by **Abdelhamid *et al.*, (2004)** Nile tilapia broodfish fed experimental diets contained graded levels of dietary protein (25, 30 and 35%) and they found that, the best body weight, daily gain and total gain of weight and body depth at different months of fry obtained by feeding their broodstock fish on a diet contained 30% CP at a rate of 1% of the body weight mass daily, particularly for the fry produced from the 1st spawning. Also they observed that, the best means of relative growth weight rate of fry were 31.8, 31.7 and 39.0 for 30% protein level, 1% feeding rate and 1st spawning, respectively.

In comparison with other fish species in aquaculture, the nutritional requirements of female tilapias are greatly affected by their unique mode of reproduction. Mouth-brooders deprive themselves of food throughout each period of oral incubation. Since female *Oreochromis* can produce several broods in succession, they may ingest food for only 4-5 days between non-feeding short feeding periods each lasting 10-13 days **(Macintosh, 1985)**. In the often short feeding periods between broods, female tilapias have to feed voraciously to regain body condition lost during incubation and to obtain energy to support further reproductive activity. Studies with tagged fish have shown that body weight loss is well correlated to the duration of incubation **(Little, 1989)**. *Oreochromis niloticus* females consumed commercial pelleted trout feed up to the equivalent of 40% of their body weight in the 48 h immediately after releasing a batch of fry.

Table (9): Least square means and standard error for the effect of month, dietary protein level and protection method on fry weight of Nile tilapia.

Variable	No.	Fry weight (g)	Temperature (°C)
Month (M)			
April (M1)	16	0.025±0.0013 a	
May (M2)	16	0.016±0.0013 b	
Protein level (P)			
25% (P1)	16	0.021±0.0013	
35% (P2)	16	0.019±0.0013	
Protection method (C)			
Covered (C1)	16	0.018±0.0013 b	
Uncovered (C2)	16	0.023±0.0013 a	
M × P			
M1 × P1	8	0.027±0.0019 a	
M1 × P2	8	0.022±0.0019 ab	
M2 × P1	8	0.015±0.0019 b	
M2 × P2	8	0.016±0.0019 b	
M × C			
M1 × C1	8	0.018±0.0019 b	
M1 × C2	8	0.031±0.0019 a	
M2 × C1	8	0.017±0.0019 b	
M2 × C2	8	0.015±0.0019 b	
P × C			
P1 × C1	8	0.017±0.0019 b	
P1 × C2	8	0.026±0.0019 a	
P2 × C1	8	0.019±0.0019 b	
P2 × C2	8	0.020±0.0019 b	
M × P × C			
M1 × P1 × C1	4	0.018±0.0027 bc	27.39
M1 × P1 × C2	4	0.036±0.0027 a	21.89
M1 × P2 × C1	4	0.018±0.0027 bc	27.39
M1 × P2 × C2	4	0.026±0.0027 b	21.89
M2 × P1 × C1	4	0.015±0.0027 c	26.95
M2 × P1 × C2	4	0.016±0.0027 c	23.75
M2 × P2 × C1	4	0.019±0.0027 bc	26.95
M2 × P2 × C2	4	0.014±0.0027 c	23.75

+ Means followed by the same letter in each column are not significantly different.

Table (10): Analysis of variance for the effect of month, dietary protein level and protection method on fry weight of Nile tilapia.

S.O.V	df	F-ratio
Month (M)	1	21.30***
Protein (P)	1	0.95
Protection (C)	1	7.81**
M × P	1	2.24
M × C	1	15.72***
P × C	1	4.06*
M × P × C	1	0.34
Remainder df	24	
Remainder MS		0.000030

* p<0.05 ** P<0.01 *** P<0.001

While commercial pelleted diets are now routinely manufactured for tilapias, little is known about the underlying nutrition of tilapia broodstock. This is especially true with respect to their lipid, essential fatty acid, vitamin and mineral requirements (reviewed by **Luquet, 1991**). The optimum level of dietary protein for growth of fry and adult tilapias seems to be about 27-35% and 25%, respectively (**Jauncey and Ross, 1982; Wee and Tuan, 1988 and Luquet, 1991**).

Uchida and King (1962) identified 35 – 40% dietary protein as optimal for fry production by tank-reared *O. mossambicus* broodfish. Good breeding results in tanks have also been obtained at Stirling University with this species and *O. niloticus* using commercial trout pellets containing 43-46% protein (**Macintosh, 1985**).

A dietary level of 35% crude protein resulted in optimum growth and spawning by *O. niloticus* broodstock held in clear-water tanks (**Wee and Tuan 1988**). In the same study, higher protein levels in the diet (42 or 50% crude protein) stimulated earlier maturation and resulted in larger eggs and slightly higher hatching rates, but had a negative effect on spawning frequency and fecundity. **DeSilva and Radampola (1990)** found that spawning frequency decreased with protein level, whereas, **Santiago *et al.*, (1982)** reported that higher dietary protein levels (40 and 50%) increased spawning frequency in *O. niloticus*.

In conclusion, the interaction between the nutritional regime of broodfish, both before and after the onset of maturation, and their spawning environment seems important in determining the strength of hierarchies between spawners and consequently their spawning performance.

4.2. Second experiment:

4.2.1. Effect of Month and tank protection on the average fry production/tank and fry weight/fish:

4.2.1.1. Fry production/tank:

The effect of month, tank protection and their interaction on fry production/tank of Nile tilapia, *Orechoromis niloticus* are presented in Table (11). As described in this table the average fry production/tank for the studied spawning months were found to be 6492, 5897, 11608 and 17106 for the four months studied, February, March, April and May, respectively.

Analysis of variance (Table 12) showed that spawning month had a significant ($P<0.001$) effect on fry production of spawning Nile tilapia females. The highest average fry number (17106/tank) was obtained during May and the lowest fry production was recorded for Nile tilapia females during March. **Ridha *et al.*, (1998)** illustrated that under ambient spawning conditions in Kuwait, peak spawning of Tilapia, *Oreochromis spilurus* occurred in May and monthly seed production was affected by changes in temperature and light duration and they concluded that seed production of *Oreochromis spilurus* in Kuwait can be extended beyond the restricted spawning season of 6 – 7 months by maintaining water temperature at 29±2°C and photoperiod at 14 h day^{-1}.

The spawning activity appeared to be influenced by water temperature. **Siddiqui *et al.* (1998)** in Saudi Arabia found that, during the period of maximum spawning activity of Nile tilapia, *O. niloticus* the water temperature was more favourable and as it started decrease from the middle of September, the spawning activity also showed a decreasing trend. However, **Mires (1982)** reported that spawning in tilapia is restricted to 5-6 consecutive months, even when the temperature is favourable all year round.

With respect to the effect of protection methods on fry production of Nile tilapia, results of Tables (11 and 12) also indicated that, fry number/tank of spawning females found to be 4929, 9063 and 16834 for the uncovered, covered and covered with heater groups, respectively. Analysis of variance (Table 12) indicated that, protection method of spawning tank had a significant effect ($P<0.001$) on fry production of Nile tilapia fry.

With regard to the effect of interaction between spawning month and protection method on fry production of Nile tilapia, Table (11) indicated that, during the first spawning month (February) there were no any fry in covered and uncovered tans because water temperature (13.0-18.0 and 18.8-23.5°C, respectively) was not suitable for spawning and hatching while the supplying covered tanks with electrical heaters increased water temperature to the most suitable temperature for reproduction process of Nile tilapia (26.0-29.1°C).

During the second spawning month (March) there were no any fry in the uncovered tanks because water temperature (15.0-20.0°C) was not suitable for spawning and embryo development. On the other hand, fry production/tank found to be 4475 in covered tanks and supplying covered tanks with electrical heaters increased fry production to 13215/tank and the same trend was also observed during the other months (April and May). The gradual increase in seed production starting from March coincides with the gradual increase in water temperature (Table, 11).

Table (11): Least square means and standard error for the effect of month, and protection method on fry production of Nile tilapia.

Variable	No.	Fry production / pond	Temperature (°C)
Month (M)			
February (M1)	24	6492±85 c	
March (M2)	24	5897±85 c	
April (M3)	24	11608±85 b	
May (M3)	24	17106±85 a	
Protection method (C)			
Uncovered without heater (C1)	32	4929±64 c	
Cover without heater (C2)	32	9063±64 b	
Cover with heater (C3)	32	16834±64 a	
M × C			
M1 × C1	8	0	13.0 – 18.0
M1 × C2	8	0	18.8 - 23.5
M1 × C3	8	19475±255 a	26.0 – 29.1
M2 × C1	8	0	15.0 – 20.0
M2 × C2	8	4475±255 f	23.0 – 25.0
M2 × C3	8	13215±255 de	27.0 – 29.0
M3 × C1	8	4500±255 f	19.0 – 25.0
M3 × C2	8	12550±255 e	24.0 – 26.0
M3 × C3	8	17775±255 ab	27.0 – 29.0
M4 × C1	8	15218±255 cd	24.0 – 26.7
M4 × C2	8	19228±255 a	25.0 – 27.0
M4 × C3	8	16873±255 bc	26.0 – 29.0

\+ Means followed by the same letter in each column are not significantly different.

Table (12) : Analysis of variance for the effect of month and protection method on fry production of Nile tilapia.

S.O.V	df	F-ratio
Month (M)	3	166.94 ***
Protection (C)	2	279.96 ***
M × C	6	47.41 ***
Remainder df	84	
Remainder MS		4175982

*** P<0.001

Analysis of variance (Table 12) indicated that, interaction between spawning month and protection method had a significant ($P<0.001$) effect on fry production of Nile tilapia.

The obtained results are in agreement with those reported by **Ridha *et al.*, (1998)** who found that no seed of *Oreochromis spilurus* in February when water temperature was lowest (18.5°C), and the sub-optimal temperature in March (24.1°C) similarly resulted in a low seed production. This demonstrates the effect of low temperature in depressing spawning performance. **Jalabert and Zohar (1982)** stated that low temperature (15.0-22.0°C) during part of the year inhibit reproduction and caused retardation of spermatogenesis in male and inhibition of exogenous vitellogenesis in females. **Maluwa and Costa-Pierce (1993)** found that temperature below 19.0°C delayed reproduction, which ceased completely below 17.0°C. **Galman *et al.*, (1988)** found that the number of spawnings obtained during the summer was double of that obtained during in the winter. **Eguia (1996)** obtained a positive correlation in seed production with temperature in different strains of tilapia.

Generally, results of Table (11) indicated that water temperature below 20°C was not suitable for spawning and embryonic development while tanks that protected and supplied with electrical heaters showed the higher fry production (19475, 13215, 17775 and 16873 fry/tank) because water temperature in these tanks (26.0-29.1, 27.0-29.0, 27.0-29.0 and 26-29°C, respectively) were very suitable for reproductive process in Nile tilapia because temperature is one of the most potent environmental factors influencing the developmental rate of fish eggs and fry (**Herzig and Winkler, 1986**).

The obtained results are in accordance with those obtained by **Rana (1990 a and b**). He found that incubation of fertilized eggs of Nile tilapia, *Oreochromis niloticus* in different incubation temperatures, 11, 17, 20, 24, 28, 30, 34.5 and 39.5°C affected embryonic survival and hatching success. At 17°C and below or at 34.5°C the proportion of embryos advancing from the cleavage stage to hatching decreased. He also reported that the optimal development to hatching (>90%) occurred at 25-30°C compared with 23.5-32°C.

Suitable temperatures for reproduction of tilapia are above 20°C (**Philippart and Ruwet, 1982** and **Popma and Lovshin, 1996**). **Srisakultiew and Wee (1988)** reported that in *O. niloticus* cool temperature treatment (22°C) induced spawning of 10-20% more females than in control treatment after 7 days. Also, **Mironova (1977)** noticed no spawning was occurred at 22°C in *O. mossambicus* and an increase in temperature from 25°C to 28-31°C increased seed production.

4.2.1.2. Average fry weight (g):

The effect of spawning month, tank protection and their interaction on the average fry weight (g) of Nile tilapia, *Orechoromis niloticus* are presented in Table (13). As described in this table the average fry weight for the studied spawning months were found to be 0.0087, 0.0087, 0.0140 and 0.0150 g/fry for the four months studies, February, March, April and May, respectively. Analysis of variance (Table 14) showed that spawning month had a significant (P<0.001) effect on fry weight of Nile tilapia. The highest average fry weight (0.015 g/fry) was obtained during May and the lowest fry weight (0.0087 g/fry) was recorded for Nile tilapia females during February and March.

With respect to the effect of protection method on fry weight of Nile tilapia, results of Tables (13 and 14) also indicated that, average fry weight of spawning females found to be 0.0078, 0.0108 and 0.0165 g for the uncovered, covered and covered with heater groups, respectively.

Analysis of variance (Table 14) indicated that, protection method of spawning tank had a significant effect (P<0.001) on the average weight of Nile tilapia fry.

With regard to the effect of interaction between spawning month and protection method on average fry weight of Nile tilapia, Table (13) indicated that, during the first spawning month (February) there were no fry in covered and uncovered tanks because water temperature (13.0-18.0 and 18.8-23.5°C, respectively) was not suitable for spawning and hatching while the supplying covered tanks with electrical heaters increased water temperature to the most suitable temperature for embryonic development of Nile tilapia, *Oreochromis niloticus* (26.0-29.1°C).

During the second spawning month (March) there were no fry in the uncovered tanks. On the other hand, fry had the same weight (0.013 g) in covered tanks and covered tanks supplied with electrical heaters. Generally the interaction between spawning month and covering method had a significant (P<0.001) effect on the average fry weight of Nile tilapia.

Table (13): Least square means and standard error for the effect of month, and protection method on fry weight (g) of Nile tilapia.

Variable	No.	Fry weight (g) / fry	Temperature (°C)
Month (M)			
February (M1)	24	0.0087±0.00010 c	
March (M2)	24	0.0087±0.00010 c	
April (M3)	24	0.0140±0.00010 b	
May (M3)	24	0.0150±0.00010 a	
Protection method (C)			
Uncovered without heater (C1)	32	0.0078±0.00007 c	
Cover without heater (C2)	32	0.0108±0.00007 b	
Cover with heater (C3)	32	0.0165±0.00007 a	
M × P			
M1 × C1	8	0	13.0 – 18.0
M1 × C2	8	0	18.8 - 23.5
M1 × C3	8	0.026±0.00030 a	26.0 – 29.1
M2 × C1	8	0	15.0 – 20.0
M2 × C2	8	0.013±0.00030 e	23.0 – 25.0
M2 × C3	8	0.013±0.00030 e	27.0 – 29.0
M3 × C1	8	0.015±0.00030 c	19.0 – 25.0
M3 × C2	8	0.014±0.00030 d	24.0 – 26.0
M3 × C3	8	0.014±0.00030 d	27.0 – 29.0
M4 × C1	8	0.016±0.00030 b	24.0 – 26.7
M4 × C2	8	0.016±0.00030 b	25.0 – 27.0
M4 × C3	8	0.013±0.00030 e	26.0 – 29.0

+ Means followed by the same letter in each column are not significantly different.

Table (14): Analysis of variance for the effect of month and protection method on fry weight of Nile tilapia.

S.O.V	df	F-ratio
Month (M)	3	505.11 ***
Protection (C)	2	1107.17 ***
M × C	6	960.94 ***
Remainder df	84	
Remainder MS		0.00000057

*** $P<0.001$

4.2.2. Effect of Month, and tank protection on growth and some reproductive traits of Nile tilapia, *Oreochromis niloticus*:

4.2.2.1. Body weight (BW) and length (BL):

Tables (15 and 16) outlined the effect of month and tank protection on some growth and reproductive traits of Nile tilapia, *Orechoromis niloticus*. As described in these tables the highest BW and BL were recorded for spawning females during March with significant ($P<0.001$) differences due to the effect of spawning month on BW and BL.

With respect to the effect of protection methods on BW and BL, results of Tables (15 and 16) also indicated that, BW and BL of spawning females did not significantly differ for the two groups uncovered without heater and cover without heater while the differences between each of these two groups and the third group (cover with heater) were significant ($P<0.01$).

The interaction between the two factors (month of spawning and protection method) indicated that the heavier and longest spawning females were recorded in March especially when electrical heaters were used for adjusting water temperature. However, the differences between BW and BL due to the interaction between these two factors were non-significant (Table, 16).

Size of female is more important than age in terms of fecundity and total number of eggs produced (**Rana, 1986** and **1988**) . Some authors have indicated that number of eggs produced is related to body length (**Welcomme, 1967; DeSilva, 1986** and

Table (15): Least square means and standard error for the effect of month, and protection method on some reproductive traits of Nile tilapia.

Variable	No.	Body weight (g)	Body length (cm)	Ovary weight (g)	GSI	Absolute fecundity	Relative fecundity
Month (M)							
January (M1)	24	241.66±8.78 b	24.08±0.35 b	2.13±0.37 b	0.85±0.12 b	981.0±61.38 b	504.4±79.0
February (M2)	16	221.90±10.75 b	22.71±0.43 c	2.19±0.46 b	0.93±0.15 b	819.7±92.07 b	494.9±96.7
March (M3)	16	283.73±10.75 a	25.57±0.43 a	4.13±0.46 a	1.41±0.15 a	2858.4±92.07 a	637.4±96.7
Protection method (C)							
Uncovered without heater (C1)	24	237.48±8.78 b	23.31±0.35 b	1.78±0.37 b	0.69±0.12 b	915.6±61.38 b	519.3±79.0
Cover without heater (C2)	16	231.54±10.75 b	24.09±0.43 b	2.17±0.46 b	0.91±0.15 b	982.8±61.38 b	538.3±96.7
Cover with heater (C3)	16	280.36±10.75 a	25.33±0.43 a	4.67±0.46 a	1.66±0.15 a	2793.4±92.07 a	571.2±96.7
M × P							
M1 × C1	8	210.60±15.19 c	22.78±0.60 c	0.83±0.64 d	0.39±0.21 d	352.1±184.1 b	338.3±136.8 b
M1 × C2	8	248.03±15.19 abc	24.69±0.60 ab	1.49±0.64 cd	0.60±0.21 cd	1258.4±184.1 b	795.1±136.8 a
M1 × C3	8	266.35±15.19 ab	24.76±0.60 ab	4.06±0.64 ab	1.57±0.21 ab	1332.5±184.1 b	378.8±136.8 ab
M2 × C1	8	228.75±15.19 bc	21.92±0.60 c	1.53±0.64 cd	0.64±0.21 cd	932.3±184.1 b	642.5±136.8 ab
M2 × C2	8	215.05±15.19 c	23.50±0.60 bc	2.85±0.64 bc	1.22±0.21 abc	707.2±184.1 b	347.3±136.8 b
M3 × C1	8	273.09±15.19 ab	25.23±0.60 ab	2.99±0.64 bc	1.06±0.21 bc	1462.6±184.1 b	577.1±136.8 ab
M3 × C3	8	294.36±15.19 a	25.89±0.60 a	5.28±0.64 a	1.75±0.21 a	4254.2±184.1 a	697.8±136.8 ab

+ Means followed by the same letter in each column are not significantly different.

Table (16) : Analysis of variance for the effect of month and protection method on some reproductive characteristics of Nile tilapia

S.O.V	df	F-ratio					
		Female length	Female weight	Ovary weight	Gonado somatic index	Absolute fecundity	Relative fecundity
Month (M)	2	11.19***	8.73 ***	6.77 **	4.36 *	9.99 ***	0.72
Protection (C)	2	6.75 **	6.42 **	13.10 ***	12.71 ***	9.03 ***	0.09
M × C	4	0.001	0.91	0.0001 **	0.41	0.0001	4.69 **
Remainder df	47						
Remainder MS		2.8923	1848.40	3.3168	0.366	2169913.39	149762.85

* P<0.05, ** P<0.001 and *** P<0.001

Rana, 1986) while others have claimed that it is more related to the body weight of the female **(Peters, 1983 and Rana, 1988)**. However, relative fecundity decreases with maternal age, weight and length **(Rana, 1986)**. Nile tilapia females of larger size were found to produce more and bigger eggs and more fry per female **(Guerrero and Guerrero, 1985)**, but smaller females spawn more frequently **(Guerrero and Guerrero, 1985)**.

Relative size of males and females may be more important as there are often hierarchies **(Noakes and Balon, 1982)** in tilapia populations based on the social dominance, which is partially determined by fish size. Male tilapias are aggressive in nature and dominant males control most of the spawning, resulting in many females not spawning. The hierarchy affects the intensity of spawning and these effects may be greater in clear water systems compared to green water systems **(Little, 1989)**. Provision of artificial nests **(Bevis, 1994)** helps to break hierarchies; thus, more females may have contact with more males and spawn. The hierarchy can also be minimized by spawning females with smaller **(Guerrero and Guerrero, 1985)** and uniformly-sized males.

Fath El-Bab (2006) indicated that absolute fecundity were found to be 1264.73, 1376.1 and 1299.84 and the averages relative fecundity were 4.14, 3.49 and 2.82 for the three females groups 300, 400 and 500g, respectively and the differences in absolute fecundity due to female body weight were significant ($P<0.01$). **Hashem and El-Agamy (1977)**, revealed that, fecundity is a function related to length, weight and age of different fish species and it increased with increase in these parameters. **Watanabe and Kuo (1985)** reported that, absolute fecundity increased by using large and old tilapia. **Rana (1988) and Bhujel (2000)** indicated that, absolute fecundity is related to body weight, while **De Silva (1986)** found that, absolute fecundity is related to body length. **Estay *et al.*, (1997)** who found that, the relative fecundity decreased with increasing of female body weight. On the other hand, **Rana (1986)** and **Bhujel (2000)** stated that, relative fecundity decreased with the decrease in age, body weight and body length of female Nile tilapia

4.2.2.2. Ovary weight (g):

Results of Table (15) indicated that the average ovary weight for spawning females as affected by spawning month were 2.13, 2.19 and 4.13 g for the three months studied, January, February and March, respectively. Analysis of variance (Table 16) showed that spawning month had a significant ($P<0.01$) effect on ovary weight of spawning Nile tilapia females. The highest average of ovary weight (4.13 g) was recorded for female in March compared that obtained during the other two months January (2.13 g) and February (2.19 g) and this may be due to the improvement in water temperature in March compared to the other two months (January and February).

With regard to the effect of protection method on ovary weight of spawning females, results of Tables (15 and 16) indicated that, covered and uncovered tanks without water heating did not significantly affect ovary weight of spawning females *O. niloticus* while ovary weight of the third female group (cover with heater) significantly ($P<0.001$) increased the ovary weight of spawning females.

The interaction between spawning month and protection method seemed to have a significant ($P<0.01$) effect on ovary weight of females where the heavier ovary weight was recorded for females spawned in cover+heater tanks during each of January (4.06 g) and March (5.28 g) and the lowest ovary weight was recorded for female group spawned in uncovered tank during the first month of spawning (January).

Chervinski (1982) reported that the activity and feeding tilapia become reduced below 20°C and feeding stops around 16°C. **Dupree and Huner (1984)** reported that tilapia becomes lethargic and stops feeding when temperature falls below 15.5°C. **Abdel-Ghany (1995)** reported that fish without feeding in winter lost significantly ($P < 0.05$) body weight. Fish received feed at either 1% or 2% of body weight gained substantial weights. Fish demonstrated poor food conversion rates (FCR) reduced growth rates but with good survival rates. Fish producers addressing spring markets could increase weight gain and improve the FCR by adjusting over winter-feeding.

4.2.2.3. Gonado-Somatic Index (GSI):

In the present study GSI varied from 0.85 (January) to 0.93 (February) and 1.41 (March) and the differences in GSI due to the effect of spawning month were significant (Table, 16). The cycle of maturation and monthly variation of GSI provides good indication of the extent of development of gonad with respect to the time of year. Gonad staging on a descriptive scale allows a rapid qualitative assessment of the breeding state and gonad weight gives a quantitative record of changes in the gonad condition (**Crossland, 1977**). In this respect **DeSilva and Chandrasoma (1980)** observed four pecks with a range of 0.35 to 1.40 in GSI of *O. mossambicus*. Also, **Hatikakoty and Biswas (2004)** reported that GSI of *O. mossambicus* varied from 0.22 (December) to 0.66 (July) and the GSI value showed four peaks in March, May, July and September.

With respect to the effect of tank protection on GSI results of Tables (15 and 16) indicated that GSI of female spawned in the uncovered tanks showed the lowest value (0.69) of GSI. On the other hand covering of spawning tanks and supplying tanks with electrical heaters increased the GSI to reach the highest value (1.66) and this may be due to the providing the optimal degree of water temperature for reproduction (Table 14).

The effect of interaction between spawning month and protection of spawning tank indicated that the highest value of SGI was recorded for female reared on sheltered tanks (1.57, 1.22 and 175) because sheltering beside supplying tanks with heaters realize optimal water temperature required for fish spawning.

Analysis of variance (Table 16) indicated that both spawning month and protection method had a significant effects ($P<0.05$ and $P<0.001$, respectively), while the interaction between the two factors did not reveal significant effect on GSI.

4.2.2.4. Absolute and relative fecundity:

Results of table (15) showed that absolute fecundity (the average number of eggs/female) for the three months January, February and March were found to be 981.0, 819.7 and 2858.4, respectively. Analysis of variance (Table 16) indicated that spawning month had a significant effect on absolute fecundity where the greatest absolute fecundity was recorded in March compared to the other spawning months. With respect to tank protection method of spawning tanks, results of the same Table (15) indicated that absolute fecundity found to be 915.6, 982.8 and 2793.4 for uncovered spawning tank, covered spawning tanks and the covered spawning tanks supplied by heaters, respectively. The differences between absolute fecundity, due to tank protection method were significant.

With regard to the effect of interaction between spawning month and protection method, results of table (15) indicated that, covering of spawning tanks increased absolute fecundity and supplying the covered spawning tanks by electrical heaters significantly ($P<0.001$) increased (table 16) absolute fecundity especially during March (4254.2) compared to January (1332.5). However, the differences between absolute fecundity, due to the interaction between spawning month and tank protection method were significant.

Water temperature, nutrition and photoperiod are considered to be the most important environmental factors that influence tilapia spawning and fecundity (**Philippart and Ruwet 1982**; **Lam, 1983** and **Brummett 1995**). **Mironova (1977)** induced reproduction of

O. mossambicus (Peters) by increasing water temperature to 28.0-31.0°C. **Ridha *et al.*, (1985)** showed the possibility of extending the spawning season of *O. spilurus* by controlling temperature alone. **Paessun and Allsion (1984)** were able to induce spawning in Nile tilapia, *O. niloticus* (L), and blue tilapia *O. aureus* (Steindachner), by controlling water temperature and photoperiod. Preliminary results obtained by **Ridha and Cruz (1998)** showed the possibility of extending the restricted spawning season of *O. Spilurus* in Kuwait to an entire year by controlling water temperature and photoperiod.

As shown in Table (15), relative fecundity (number of egg/g of female body weight) for the three months January, February and March were found to be 504.4, 494.9 and 637.4, respectively. Analysis of variance (Table 16) indicated that neither spawning month nor protection method had significant effect on relative fecundity, i.e the number of eggs in gram of female body weight did not change from month to another during the spawning season. However, the differences between relative fecundity, due to the interaction between spawning month and tank protection method were significant ($P<0.01$).

4.2.3. Correlation coefficients between some reproductive traits of Nile tilapia, *Oreochromis niloticus*:

Correlation coefficients between reproductive traits of Nile tilapia, *Oreochromis niloticus* are presented in Table (17). As shown in this table female body length is significantly and positively correlated with each of body weight (0.80), ovary weight (0.508)

Table (17) : Correlation coefficient between body weight, body length and some reproductive traits of Nile tilapia, *Oreochromis niloticus*

	Body length	Body weight	Ovary weight	Gonado somatoic index	Relative fecundity
Body weight	0.80 ***				
Ovary weight	0.508 ***	0.606 ***			
Gonado somatoic index	0.394 **	0.424 ***	0.968 ***		
Relative fecundity	0.018	0.112	0.007	- 0.040	
Absolute fecundity	0.373 **	0.496 ***	0.660 ***	0.576 ***	0.547 ***

GSI (0.394) and number of egg/female (0.373). Also, the correlation coefficient between body weight was significantly and positively correlated with ovary weight (0.606), GSI (0.424) and absolute fecundity (0.496). On the other hand, **Cisse (1988)** found non significant correlation between body weight of *Sarotherodon melanotheron* and absolute fecundity. For black carp, **Graah (2001)** found that correlation coefficient between body weight and egg number per one gram was 0.33 ($P<0.05$).

The obtained correlation coefficients between body weight and the different reproductive traits outlined above indicates that as the female body weight and length increased, ovary weight, GSI, relative fecundity and absolute fecundity increased. Similar results for black carp were obtained by **Graah (2001)** who found that as the female body weight increased, most of reproductive traits (egg weight per fish, egg weight/kg, absolute and relative fecundity, egg number for one gm egg, larvae number/fish larvae number/kg, and fry number /fish) significantly increased but the fry number/kg and fry viability (after 10 days from hatching) decreased.

Results of Table (17) also indicated that, ovary weight was positively and significantly correlated with GSI (0.968)) and absolute fecundity (0.660), and the same trend was also observed for correlation coefficient between each of GSI and absolute fecundity (0.576) and between absolute fecundity and relative (0.547). **Graah (2001)** found that, average number of eggs/gram egg was positive and significantly correlated with female body weight (0.34); relative fecundity did not significantly correlated with each of all the studied reproductive performance traits of black carp.

In conclusion, protection methods of spawning tanks with heater had a significant effect on weight of Nile tilapia fry. Also, a positive correlation between body weight and relative and absolute fecundity.