



Growth and Production of Raft Cultivated Mediterranean Mussel (*Mytilus galloprovincialis* Lamarck, 1819) in Sinop, Black Sea

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Abstract

Mussel culture was practiced in the raft system in Sinop area, Black Sea, from May 2005 to May 2006. One-year old rope grown mussel with a mean length of 40.28±0.51 mm and a mean live weight of 6.06±0.20 g were stocked in nylon socks, and suspended from the raft system. Effects of environmental factors including temperature, salinity, chlorophyll *a*, seston, particulate inorganic matter and particulate organic matter on some growth parameters were monitored during the experimental period. At the end of the experimental period, the mean mussel shell length was 58.86±2.81 mm, while mean live weight was 18.53±2.25 g. The growth rate was low during the winter and resumed in March. The monthly distribution of meat yield changed between 16.23 and 23.93% with a mean of 20.55±0.78%. The minimum and maximum meat yield were in April and July, respectively. There was a positive correlation between meat yield and particulate organic matter (P<0.05). The highest value of Specific Growth Rate (SGR) was in the first four months when the mussels were smaller size and food availability was higher. The final production was 7.97±0.18 kg per meter of rope. In the light of these results, mussel culture in the raft system was discussed.

Keywords: mussel cultivation, raft system, *Mytilus galloprovincialis*, Black Sea.

Karadeniz'de Sinop İlinde Akdeniz Midyesinin (*Mytilus galloprovincialis* Lamarck, 1819) Sal Sisteminde Büyümesi ve Üretimi

Özet

Mayıs 2005 ile Mayıs 2006 arasında, Karadeniz bölgesi Sinop ilinde sal sisteminde midye yetiştiriciliği çalışması yapılmıştır. Ortalama boyu 40,28±0,51 mm ve ortalama ağırlığı 6,06±0,20 g olan bir yaşındaki midyeler naylon çuvallara doldurularak, sal sisteminden asılan halatlarda büyütülmüştür. Deneme süresince çevresel faktörlerin (sıcaklık, tulumluk, klorofil-a, seston, partikül organik madde ve partikül inorganik madde) bazı büyüme parametrelerine etkisi izlenmiştir. Deneme sonunda, midyelerde boy 40,28 ile 71,72 mm arasında değişerek ortalama 58,86±2,81 mm, canlı ağırlığı ise 6,06 g ile 31,89 g arasında dağılım göstererek ortalama 18,53±2,25 g olarak ölçülmüştür. Büyüme oranı kış aylarında düşmüş ve Mart ayında tekrar artmaya başlamıştır. Et veriminin aylık değişimi %16,23 ile %23,93 arasında değişmiş beraber olup ortalama %20,55±0,78 olarak ölçülmüştür. En düşük et verimi değeri Nisan ayında elde edilirken en yüksek değer Temmuz ayında elde edilmiştir. Et verimi ve partikül organik madde arasında pozitif ilişki bulunmuştur (P<0,05). Çalışmada en yüksek spesifik büyüme oranı, midyelerin daha küçük ve besin miktarının daha fazla olduğu ilk dört ayda gerçekleşmiştir. Deneme sonunda yetiştirme halatının bir metresinde elde edilen ürün miktarı 7,97±0,18 kg olarak bulunmuştur. Elde edilen bu bulgular sonucunda sal sisteminde midye yetiştiriciliği tartışılmıştır.

Anahtar Kelimeler: midye yetiştiriciliği, sal sistemi, *Mytilus galloprovincialis*, Karadeniz.

Introduction

Aquaculture is a developing industry in Turkey, enjoying a great potential for development both in freshwater and marine ecosystems. The contribution

of aquaculture production to the total fish supply was 18.1% in 2007 and it was increased 9% in comparison to previous year. The most important species in cultivation is trout (*Oncorhynchus mykiss*) (41.8%) followed by sea bass (*Dicentrarchus labrax*) (30%)

and gilthead sea bream (*Sparus aurata*) (24%). Total aquaculture production in 2007 reached 139,873 t while *Mytilus galloprovincialis* culture was only 1,100 t (TURKSTAT, 2008).

The culture of marine organisms in the Black Sea region is a relatively recent development and not yet widespread. However prospects for mussel culture in the Black Sea are quite high due to the favorable salinity, temperature, topography, food availability, reproductive potential and socio-economic conditions in this area. But, there is not any mussel farm in the Black Sea while there are two mussel farms in the Marmara Sea and Aegean Sea in Turkey.

Mussel culture can be practiced in various systems, including suspended culture (using rafts or longline) and bottom culture (by seeding intertidal area) (Hickman, 1992). Suspended mussel culture exhibited higher performance in comparison to bottom and pole culture (Garen *et al.*, 2004). In comparison with longline system, raft systems have several advantages like having working place, easiness to work in rough weather and occupying fewer surfaces (Karayücel, 1997). *M. galloprovincialis* is a filter feeding animal, which depends upon phytoplankton, organic detritus, bacteria and probably dissolved organic matter in the water as sources of food. Mussel (*Mytilus* spp.) farming is no doubt the most efficient way to convert the organic matter produced by marine organisms of the first link of the food chain (phytoplankton and remains thereof) in to palatable and nutritious human food (Korringa, 1976).

Several authors documented the close relationship between mussel growth efficiency and food availability, indicating the growth performance limits in terms of energetic potential of food available (Fréchette and Bourget, 1985; Karayücel and Karayücel, 2000; Karayücel *et al.*, 2003b; Erdemir Yiğın and Tunçer, 2004; Ogilvie *et al.*, 2004; Lemaire *et al.*, 2006; Ozernyurk and Zotin, 2006; Strohmeier *et al.*, 2008). Both general and local environmental parameters influence the growth rate. General factors include water temperature and salinity, which may

affect the rates of biochemical reactions in organisms in temperate latitudes. Local factors that determine nutritional conditions can greatly influence the growth rate of marine bivalves (Karayücel and Karayücel, 2000; Karayücel *et al.*, 2003a; Erdemir Yiğın and Tuncer, 2004; Ozernyurk and Zotin, 2006; Yıldız *et al.*, 2006; Peharda *et al.*, 2007). Important factors in growth rate are particulate organic matter (Thompson and Nickols, 1988; Garen *et al.*, 2004), duration of air exposure (Seed, 1969), population density (Peterson and Beal, 1989; Ramsay *et al.*, 2008), genotypic characteristic (Dickie *et al.*, 1984; Skidmore and Chew, 1985) and water current velocity (Grizzle and Morin, 1989).

Today, mussel culture in raft system is carried out commonly in many countries all over the world (Sánchez-Mata and Mora, 2000). But there is no known study about mussel culture in the raft system in Black Sea and therefore the present study constitutes and encourages a model for local entrepreneurs.

Materials and Methods

Mussel culture in the raft system was carried out at the depth of 13 m in Sinop, in the Black Sea, Turkey (Figure 1) from May 2005 to May 2006.

System Design

Raft system was mainly constructed from steel pine wood beams and iron sac (Figure 2). For building raft system, two sac float with 3.5 mm thickness, 50x75x300 cm dimensions were used. Three steel bar (0.8x12x400 cm) were attached to the float diagonally while six pine wood beams (10x10x400 cm) were attached to steel bars by steel screws.

The raft system was moored from four sides of the raft by using concreted block and 32 mm polypropylene riser (4:1 scope). Each concreted block was connected to riser rope with 10 meters of 22 mm open link ground chain. Two rectangle sacs with 3.5

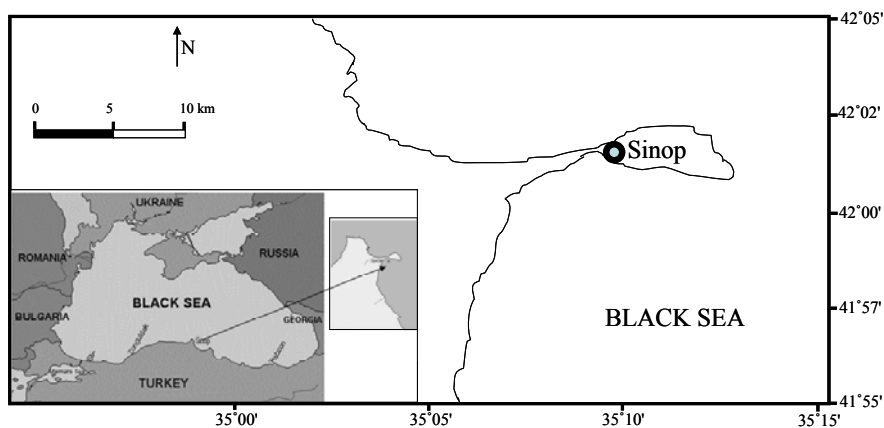


Figure 1. The map of the study area.



Figure 2. The experimental raft system for mussel culture.

thickness were used as floats and 4 mm of angle iron welded all over corners of sacs to make the float system strong. Then two rectangle float were combined by two meters galvanized pipe from the bottom of floats.

Polypropilen culture ropes with 18 mm diameter and 6 m length were suspended from the pine woods at 50 cm intervals. Twenty-five cm of wooden pegs (25×2×2 cm) inserted crosswise to 18 mm nylon rope with 30-50 cm intervals and 3 kg concreted weight tied to the end of culture rope against wave action and tangle of culture rope. Prepared culture ropes were inserted to factory type nylon socks (mesh size 1 cm) and filled with seed (mean a length of 40.28±0.51 mm) and a total of 15 ropes were suspended from the raft system.

Sampling Procedure

One year old mussels with mean length of 40.28±0.51 mm collected from mooring rope of Ak Fish Farm and stocked to nylon socks at a density of 965±31 individuals for per meter of rope and suspended from raft system. Monthly sampling was carried out for environmental and biometric parameters. Each month, three ropes were selected and 30 cm section of each rope was grazed for mussel sampling. Mussels from each rope were individually counted and recorded then all mussels were scrubbed for encrusting organism (e.g. barnacles, epifauna and seaweeds) and sub-samples (Fifteen mussels) were taken to measure biometric parameters. Sub-samples were taken to determine monthly changes in shell length (SL), tissue weight (wet meat weight (WMW), live weight (LW), dry meat weight (DMW) and ash-free dry meat weight (AFDMW).

Environmental Parameters

Temperature, salinity, chlorophyll *a*, seston (total particulate matter), particulate inorganic matter (PIM) and particulate organic matter (POM), were determined monthly from May 2005 to May 2006. Water samples were taken at depth of 3 m by using a Niskin bottle at the experimental site. Water

temperature and salinity was measured in situ using a probe (YSI 6600). In the laboratory, triplicate water samples (3 L) were filtered onto Whatman GF/C fillters to determine chlorophyll *a* (µg/L), seston (mg/L) and POM (mg/L) concentration according to Stirling (1985).

Morphological Measurements and Statistical Analyses

Growth was estimated from changes in shell length, live weight and wet meat weight (tissue weight). Live weight (total weight of mussel) was measured by weighing live animals and wet meat weight obtained by weighing the meat after dissecting and blotting the extra water with a tissue paper of mussel. Shell length (maximum from anterior to posterior axis) was measured to the nearest 0.1 mm with a caliper (Seed, 1969). At the end of the experiment, mussels from three ropes were counted and the number of mussels per meter of rope calculated for production. Production was estimated according to the Rivonker *et al.* (1993). Meat yield was calculated by dividing the wet meat weight to live weight of mussel (Chatterji *et al.*, 1984). Monthly specific growth rate (SGR %) were found from following formulate;

$$(SGR \%) = [(\ln L_2 - \ln L_1) / (T_2 - T_1)] \times 100$$

where L_1 and L_2 are the mean shell lengths at times T_1 and T_2 (Chatterji *et al.*, 1984).

A correlation matrix analysis was used to determine the relationships between the environmental and growth parameters. Statistical analyses were carried out by using MINITAB 13.1 software.

Results

Environmental Parameters

Environmental parameters were shown in Figure 3. The temperature ranged from 7.5°C in February to 25.05°C in August with a mean of 14.90±1.70°C.

Salinity ranged from 16.80 to 17.97 psu with a mean of 17.59 ± 0.10 psu and there was not clear seasonal pattern. Chlorophyll *a* peaked in March ($16.30 \mu\text{g/L}$) as a result of spring algal bloom and decreased to the lowest value in January ($0.53 \mu\text{g/L}$), with an annual mean of $3.07 \pm 1.18 \mu\text{g/L}$. Seasonal chlorophyll *a* concentration was significantly different ($P < 0.05$) and in general higher in spring and lower in winter. POM

ranged from 1.58 to 4 mg/L with a mean of 2.42 ± 0.17 mg/L while seston ranged from 5.45 to 6.92 mg/L, with a mean of 6.21 ± 0.12 mg/L. There was a positive correlation between chlorophyll *a* and POM ($P < 0.05$) while salinity and temperature did not significantly correlate with chlorophyll *a*, POM and seston (Table 1). While chlorophyll *a* and seston reached maximum values in March, the maximal temperature value was

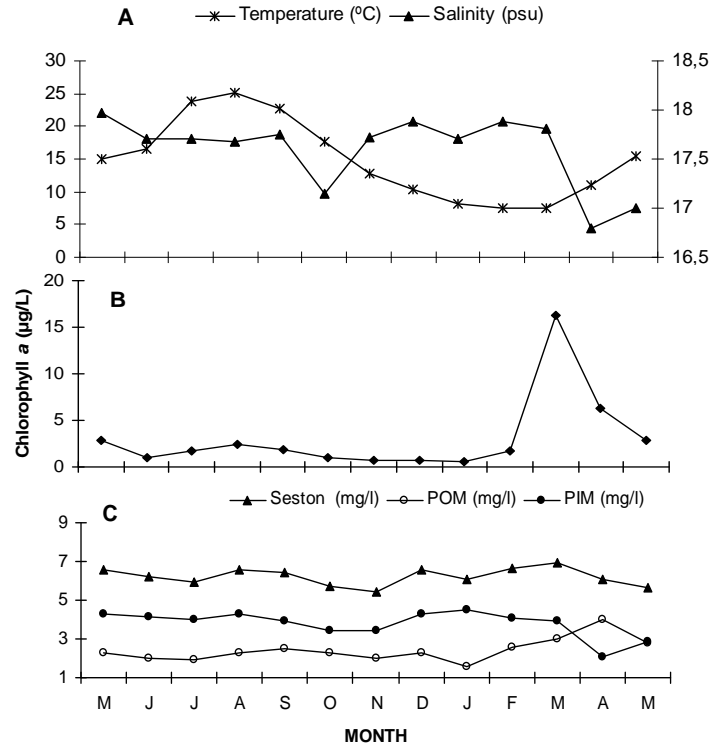


Figure 3. Monthly distribution of mean temperature, salinity (A), chlorophyll *a* (B) and mean particulate organic matter, particulate inorganic matter and seston (C) from May 2005 to May 2006.

Table 1. Correlations matrix analysis for Seston

	Seston	POM	Ch-a	PIM	Temp	WMW	MY	DMW	SL
POM	0.178								
Ch-a	0.465	0.574							
PIM	0.493	-0.768	-0.205						
Temp	-0.164	-0.224	-0.329	0.091					
WMW	0.120	0.316	0.326	-0.202	-0.738				
MY	0.360	-0.692	-0.281	0.847	0.049	-0.236			
DMW	-0.007	-0.402	-0.0394	0.351	0.178	0.128	0.337		
SL	-0.116	0.505	0.333	-0.522	-0.621	0.923	-0.550	0.006	
LW	-0.124	0.549	0.367	-0.566	-0.618	0.895	-0.576	-0.143	0.986
	0.688	0.052	0.218	0.044	0.024	0.000	0.039	0.641	0.000

Particulate Organic Matter (POM), Chlorophyll-*a* (Ch-a), Particulate Inorganic Matter (PIM), Temperature (Temp), Mean Wet Meat Weight (WMW), Mean Meat Yield (MY), Dry Meat Weight (DMW), Mean Shell Length (SL), Mean Live Weight (LW)
Cell Contents: Pearson correlation P-Value

remarked in August. There was a clear seasonal pattern in the temperature but the other environmental parameters did not show any seasonal pattern.

Growth Rate

Monthly changes in shell length, live weight and wet meat weight were depicted in Figure 4. At the end of thirteen months, the average shell length increment was 31.44 mm and mean shell length reached to 71.72 ± 0.53 mm. Total of 39.36% shell length growth occurred from May to October. The growth rate was very low during the winter and resumed in March. The average live weight increment

was 25.83 g and mussels reached mean live weight of 31.89 ± 2.25 g. At the end of the experiment, the mean wet meat weight (tissue weight) was 4.16 ± 0.47 g while the shell weight was 6.76 ± 0.74 g. Meat yield is shown in Figure 5 that ranged from 16.23 to 23.93% with a mean of $20.55 \pm 0.78\%$ and it correlated with POM ($P < 0.05$). The shell length increment positively correlated with live weight ($P < 0.05$). The monthly specific growth rate (SGR%) ranged from 1.42-13.81% with a mean value of $5.34 \pm 1.05\%$. The highest values of SGR were obtained in the first four months when the mussels were younger and availability of food was higher.

Monthly mussel density and production are

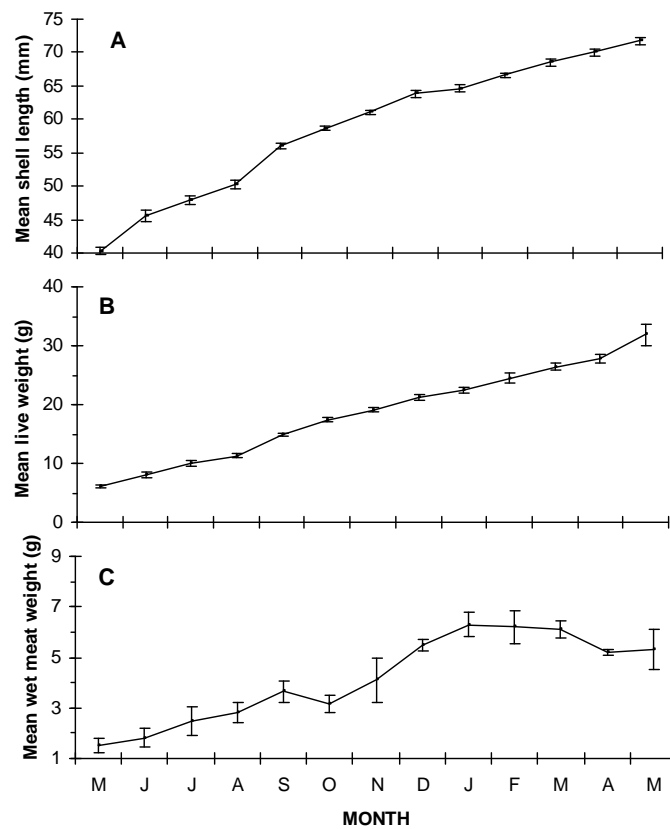


Figure 4. Monthly distribution of mean shell length (A), live weight (B) and wet meat weight (C) with standard error from May 2005 to May 2006.

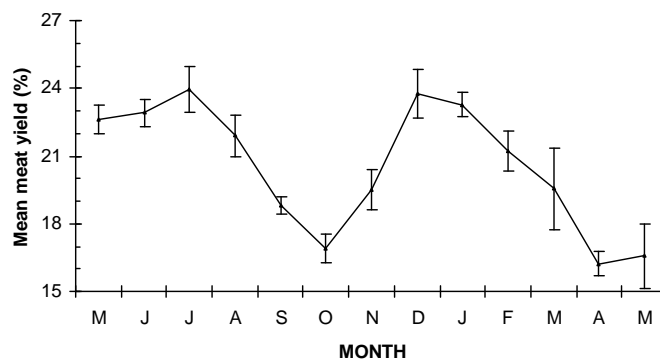


Figure 5. Monthly distribution of mean meat yield from May 2005 to May 2006.

given in Figure 6. The final mean mussel density was 250 ± 5.09 mussels per meter of rope and the final production was found to be 7.97 ± 0.18 kg per meter of rope in the raft system.

Discussion

Growth of marine bivalves is affected by several environmental factors such as water temperature, food supply, salinity, water current velocity but temperature and phytoplankton availability are the most important factors (Jones and Iwama, 1991; Karayücel and Karayücel, 1999; Manoj Nair and Appukuttan, 2003; Ren and Ross, 2005). Bayne (1976) reported that when temperature is above 10°C and food is available, growth rate is high. In this study, when the temperature is below 10°C in March, chlorophyll *a* reached the highest value ($16.3 \mu\text{g/L}$) and POM reached maximum ($4.00 \pm 0.29 \text{ mg/L}$) in the April and positively correlated with chlorophyll *a* and POM ($P < 0.05$). When the seston was lower, the increase in shell length and live weight were lower, too. However when the POM and chlorophyll *a* were higher in the spring and summer, live weight and shell length were higher, too. There was a positive correlation between shell length and live weight. Chlorophyll *a* and POM had a significant correlation between seston and had higher values, compared with those of other highly productive areas for bivalve culture (Stirling and Okumuş, 1994; Stirling and Okumus, 1995; Sarà et al., 1998; Lök et al., 2007). Karayücel et al. (2003b) reported that the SGR was lower during the winter due to the low availability of food but it resumed in March and continued through the spring and summer in Sinop, in the Black Sea. These findings are similar with the present study. Seston was high in the spring and summer, while it

was low in the winter. Some authors (Widdows et al., 1979; Rodhouse et al., 1984a; Bayne et al., 1987; Garen et al., 2004) reported that the mussel growth rate was lower when seston concentration was low. These results are similar with this study. The most important factor is nutrient matter for mussel growth (Mohlenberg and Riisgård, 1979; Ogilvie et al., 2004; Lemaire et al., 2006). Growth was correlated with food supply in the environment (Page and Hubbard, 1987; Ogilvie et al., 2004).

The highest SGR values were measured during spring and summer when mussels were younger and while temperature and food availability were higher. Some authors (Karayücel and Karayücel, 2001; Karayücel et al., 2002; Lauzon-Guay et al., 2005; Lök et al., 2007) declared similar findings. Older mussels have a slower growth rate (Seed, 1969; Lauzon-Guay et al., 2005; Lök et al., 2007). Kautsky (1982) found that reproductive tissues account for 50% of the total soft body weight of *Mytilus edulis*. Rodhouse et al., (1984b) demonstrated that in large mussels over 90% of the energy goes into gamete production. The combined effects of reduced feeding rate and increased gamete production in older mussels may be responsible for their slow growth (Thompson, 1984; Karayücel et al., 2002; Lauzon-Guay et al., 2005). The meat yield decreased after reproduction (Kopp et al., 2005). Flesh weight was subject to seasonal fluctuations associated with the reproductive cycle (Gosling, 2003). In the present study, the wet meat weight had a rapid decrease in April-May and October due to the gonad release. The wet meat weight increased from November to March while new gonad reserves were built. Meat yield positively correlated with POM ($P < 0.05$). Seasonal changes in wet meat weight result from the storage and utilization of food reserves in relation to the complex

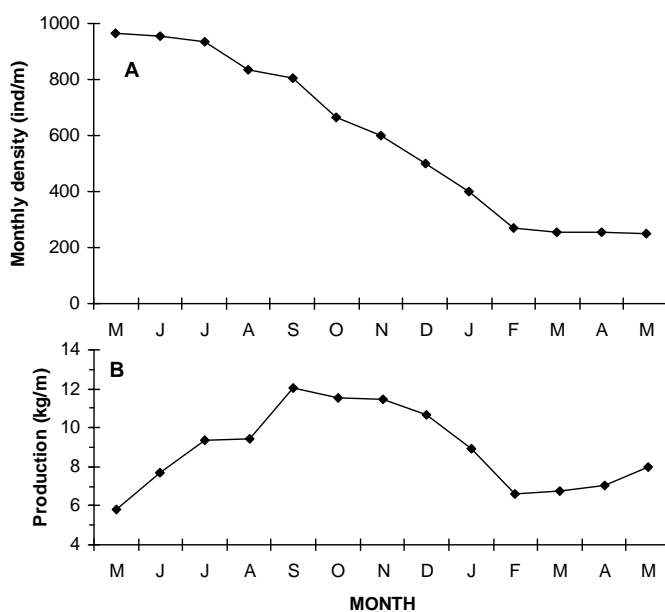


Figure 6. Monthly distribution of mean cumulative density (A) and production (B) from May 2005 to May 2006.

interaction of food availability and temperature with growth and reproductive processes (Dare and Davies, 1975).

In this study, mussel culture in the raft system took two years from spat settlement on collectors to harvest in the Black sea, Turkey. Similar results were reported for longline system by Karayücel *et al.*, (2003b) that culture requires two years from spat settlement until market size (>60 mm) in the Black sea. In Scotland cultivated mussels in raft system reach market size in 2.5–3 years (Karayücel, 1997). In the Irish Sea transplanted spat reached market size of 60 mm in suspended system at between 2.5-3 years (Dare and Davies, 1975). These differences in growth can be result of different temperature and food availability. Okumus (1993) reported 6.1 kg on the west coast of Scotland in 2 years. The bulk of the Croatian mussel aquaculture is in the areas of the Lim channel, Krka estuary and Mali Ston Bay, which are moderately eutrophic areas compared with the otherwise mainly oligotrophic coastal waters (Viličić, 1989). Production cycle in those areas range from 1.5 to 2 years (Hrs-Brenko and Filić, 1973; Benović, 1997).

There is a good interest in shellfish culture in Turkey. Mussel is non-mobile of limited mobility. Therefore they can be kept in captivity without the need for constant attention and artificial feeding and easy harvest. All these results showed that the Black Sea has a good potential for mussel culture in different techniques due to favourable environment which can support growth almost all over the year and almost entirely free from pests, diseases, chemical pollution. Moreover fisheries is one of the lifestyle of Black sea's people can encourage the mussel culture in home made raft system, decrease unemployment and gives opportunity culture of marine animals other than fish in the Black sea.

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