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Determination of Hatching Performance, Yolk-Sac Absorption, and Larval Growth Rates in Abant Trout (*Salmo trutta abanticus*), Brook Trout (*Salvelinus fontinalis*), and their Hybrids

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ABSTRACT: In this study, hatching performance, yolk-sac absorption, and growth rates of Abant trout (*Salmo trutta abanticus*), brook trout (*Salvelinus fontinalis*), and their hybrids were investigated. In this context, relationships between duration (days) and total larvae length, total larvae wet weight, dry larvae body weight and yolk-sac weights, and larval growth were determined. At the end of the study, eye pigmentation, hatching, and larval survival rates were defined as 99.50%, 97.68%, 98.97% for Abant trout, 87.35%, 68.97%, 71.54% for brook trout, 96.12%, 64.18%, 56.82% for *S.t.a.* ♀ x *S.f.* ♂ hybrid and 14.98%, 0.45% for *S.f.* ♀ x *S.t.a.* ♂ hybrid respectively. The results indicated that there were significant relationships between degree-day and length, total wet weight, dry larvae body weight, and dry yolk-sac weight in Abant trout, brook trout, and their hybrids. This relationship was demonstrated as decreasing in the yolk-sac and as increasing in others. As a result of crossing, it was observed that the hatching efficiency of hybrid (*S.t.a.* ♀ x *S.f.* ♂) was similar to brook trout, and growth performance was similar to Abant trout. The results will help further studies and will contribute to the management practices of the stocks of Abant trout, brook trout, and their hybrids.

Keywords: Abant trout; Brook trout; Hybrid; Hatching performances; Yolk-sac absorption.

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INTRODUCTION

Aquaculture production is rapidly increasing and is considered as an alternative food source around the world. In the aquaculture industry, biotechnological applications are used to increase the amount of product and reduce the production cost like other industries. The hybrid fish production, the formation of a new species that occurs by crossing two different fish species, is one of the methods that gain importance day by day in culture conditions. Hybrid fish may have different characteristics from their parents (Blanc and Chevassus, 1986; Mckay et al., 1992a; Mckay et al., 1992b; Scribner et al., 2001;Seiler and Keeley 2007; Şahin et al., 2011; Rahman et al., 2013; Shechonge et al., 2018; Selz and Seehausen, 2019; Fraser et al., 2021). The desired goal of hybridization is to produce better growth performance and feed utilization than parents, meat quality, disease resistance, and sterile fish (Bartley et al., 2001; Başçınar et al., 2010). Hybrid fish production has been carried out on different trout species (Chevassus, 1979; Blanc and Chevassus, 1979) such as brown trout x brook trout (*Salmo trutta* x *Salvelinus fontinalis*) (Scheerer and Thorgaard, 1983), Atlantic salmon x brown trout (*Salmo salar* x *S. trutta*) (Galbreath and Thorgaard, 1997), lake trout x brook trout (*Salvelinus namaycush* x *S. fontinalis*) (Snucins, 1992), rainbow trout x char (*Oncorhynchus mykiss* x *Salvelinus sp.*) (Dorson et al., 1991; Bartley et al., 2001), Black Sea trout x rainbow trout (*Salmo labrax* x *Oncorhynchus mykis*) (Akhan et al., 2011a, b).

Abant trout (*Salmo trutta abanticus*), which belongs to the salmonidae family, is an endemic trout in Turkey. Its habitat is Abant Lake, and nearby rivers and streams (Turan et al., 2009). Brook trout (*S. fontinalis*) is an American salmonidae species and is commercially important in North America, Europe, Asia, Africa, and South America. This species is also commercially grown in some trout farms in the Eastern Black Sea region of Turkey (Başçınar et al., 2010; Önder et al., 2016). Brook trout typically grows slower than rainbow trout under these culture conditions (Fischer et al., 2009), so its intensive farming is not common as well as rainbow trout.

The yolk-sac constitutes the main nutritional resource during embryonic development and reaches up to the end of the first feeding phase (free swimming) which is of critical importance for the improved survival and larval quality. The first feeding starts in the trout when more than 30% of the alevin starts free-swimming (Başçınar et al., 2003; Başçınar, 2010). Several studies have been performed on larval development of salmonid species; for example, Atlantic salmon (*Salmo salar*) (Hansen and Møller, 1985; Peterson and Martin-Robichaud 1995), rainbow trout (*Salmo gairdneri*) (Hodson and Blunt, 1986) (*O. mykiss*) (Başçınar, 2010), sea trout (*Salmo trutta*) (Hansen, 1985), brook trout (Başçınar et al., 2003; Önder 2016), brown trout (*Salmo trutta macrostigma*) (Demir et al., 2010), Black sea trout (*Salmo trutta labrax*) (Başçınar et al., 2005; Kocabaş et al., 2016), and Abant trout (Kocabaş et al., 2011). In addition, the larval development of hybrid trout was also investigated like brook trout and Arctic charr (*Salvelinus alpinus*) and their hybrids (Dumas et al., 1996), black sea trout and brook trout and their hybrids (Başçınar et al., 2010), Black Sea trout and rainbow trout and their hybrids (Akhan et al., 2011a).

There are many studies in the literature search as above brook trout and Abant trout; however, no studies have been found on the hybridization of both species, hatching performance in hybrids, yolk-sac consumption, and larvae growth. In this study, we aimed to check the possibility of successful hybridization between brook trout and Abant trout and thus investigated hybridization success in hatching performances, yolk-sac absorptions and larval growth performance.

MATERIAL AND METHODS

Broodstock

The eggs and milt were collected from 5 females (33.88±1.90 cm, 612.00±64.64 g) and 4 males (35.45±1.23 cm, 737.75±93.84 g) of brook trout (2^+ years-old); 2 females (43.95±8.55 cm, 1133.00±729.23 g) and 3 males (26.91±3.61 cm, 246.00±133.00 g) of Abant trout (3^+ years-old), respectively. Spawning, hybridization, hatchery performance, and yolk-sac consumption studies were carried out at Karadeniz Technical University, Faculty of Marine Sciences.

Experimental design and hybridization

Four cross-types were produced: Abant torut (*Salmo trutta abanticus* ♀ x *Salmo trutta abanticus*♂ (*S.t.a.* ♀ x *S.t.a.* ♂)), brook trout (*Salvelinus fontinalis* ♀ x *Salvelinus fontinalis* ♂ (*S.f.* ♀ x *S.f.* ♂)) and the hybrids between brook trout and Abant trout (*Salmo trutta abanticus* ♀ x *Salvelinus fontinalis* ♂ (*S.t.a.* ♀ x *S.f.* ♂) and *Salvelinus fontinalis* ♀ x *Salmo trutta abanticus* ♂ (*S.f.* ♀ x *S.t.a.* ♂)). Egg numbers were placed in the incubator as 2511 brook trout, 994 Abant trout, 2791 hybrids (*S.t.a.* ♀ x *S.f.* ♂), and 3644 hybrids (*S.f.* ♀ x *S.t.a.* ♂). Dead eggs and dead larvae were recorded. Temperature was measured two times a day.

Sampling of larvae and yolk-sac absorption

The alevin sampling was commenced at 7 day intervals from hatching. The first larvae were sampled at 446 degree-day in the Abant Trout (*S.t.a.* ♀ x *S.t.a.* ♂) group, 532 degree-day in the brook trout (*S.f.* ♀ x *S.f.* ♂), and 472 degree-day in the hybrid (*S.t.a.* ♀ x *S.f.* ♂). The experiment was set up with 300 larvae in each group. Sampling was performed randomly by taking 10 samples every week. This process was continued until the yolk-sacs of larvae were completely consumed. All larvae were fed with trout fry feed (57% protein, 17% lipid) (Skretting®, Norway) after yolk-sac absorption was completed (day 28^{th}) in Abant trout. After three weeks, the yolk-sacs and bodies of the fixed larvae were separated from the sacs using a forceps and scalpel, and their weights were measured separately. It was dried in the oven at 60 °C for 48 hours (Hansen, 1985; Hodson and Blunt, 1986).

Measurements

The relationships among brook trout, Abant trout, and their hybrids' incubation performance, yolk-sac consumption until free swimming, larval growth rate, daily weight gain (mg), daily length (mm), total wet weight, dry larvae body weight, and dry yolk-sac weight were determined. Dry yolk-sac consumption rate (mg/day) was calculated as $YCR = (Y_0-Y_t)/t$, daily length growth rate (mm/day) as $LGR = (l_t-l_0)/t$, daily weight growth rate (mg/day) as $WGR = (W_t-W_0)/t$, Specific Growth Rate as $SGR\ (\%\ day^{-1}) = 100 \times ([\ln W_t - \ln W_0]/\text{feeding days})$ and development index as $K_D = 10\ (\text{Wet wt}^{1/3})/\text{length}$, where, Y_0 is the initial yolk-sac dry weight; Y_t is the yolk-sac dry weight at time (day) t; l_0 is the initial alevin length; l_t is the alevin length at time (day) t; W_0 is the initial wet weight; W_t is the wet weight at time (day) t; t is the number of days (Peterson and Martin-Robichaud, 1995; Başçınaret al., 2005; Başçınar, 2010; Başçınaret al., 2010; Kocabaşet al., 2012; Önder et al., 2016; Korkut et al. 2007). Some liquid flows out during yolk-sac consumption' studies and this amount cannot be determined exactly, so dry weights are preferred for some calculations (Hansen and Møller, 1985).

Statistical analysis

At the end of the study, MINITAB® and MS EXCEL® softwarepackage programs were used to evaluate the data. Regression analysis was used to determine the relationships in statistical analysis, and covariance analysis was used to compare the regression coefficients.Comparison of growth parameters of larvae was evaluated using one-way analysis of variance (one-way ANOVA) (Peterson and Martin-Robichaud, 1995; Başçınar 2010; Başçınar et al., 2010; Önder et al., 2016). Means were examined for significant differences among the groups using Duncan's multiple range test ($P<0.001$).

RESULTS

Hatching efficiency

During experimental procedures, the water temperature was recorded as 11.87±0.94 (7.5-13.0) °C for incubation and the yolk-sac consumption temperature of the larvae was recorded as 12.32±0.65 (11.1-13.6) °C between 0 and 28 days and 13.20±0.81 (10.3-14.2) °C between 29 and 56 days. Egg sizes of brook trout and Abant trout were determined as 4.11±0.13 mm (3.92-4.25) and 4.76±0.79 mm (4.20-5.33), respectively. The eyed-eggs, hatching and free swimming times and rates of eggs are given in Table 1. The highest hatching rates were found as 97.68% in the Abant

Table 1. Eyed-egg stages, hatching, and free-swimming times (days) of brook trout, Abant trout, and their hybrids (days-degrees in brackets)

	Brook Trout (*S.f.* ♀ x *S.f.* ♂)	**Abant Trout (*S.t.a.* ♀ x *S.t.a.* ♂)**	**Hybrid (*S.t.a.* ♀ x *S.f.* ♂)**	**Hybrid (*S.f.* ♀ x *S.t.a.* ♂)**
Eyed-egg stage (day)	19-25 (228-302)	19-23 (228-278)	19-24 (228-289)	19-24 (228-289)
Eyed-eggs (%)	87.35	99.50	96.12	14.98
Hatching stage (day)	34-45 (420-553)	32-37 (393-458)	32-40 (393-494)	32-37 (393-458)
Hatching rate (%)	68.97	97.68	64.18	0.45
Swim-up stage (day)	66-73 (818-912)	58-65 (714-805)	59-67 (728-832)	-
Larval survival rate (%)	71.54	98.97	56.82	-

Trout (*S.t.a.* ♀ x *S.t.a* ♂) group, 68.97% in the brook trout (*S.f.* ♀ x *S.f.* ♂), 64.18% in the hybrid (*S.t.a.* ♀ x *S.f.* ♂), and 0.45% in the hybrid (*S.f.* ♀ x *S.t.a* ♂). Yolk-sac consumption could not be observed in the hybrid (*S.f.* ♀ x *S.t.a.* ♂) group due to insufficient hatching larvae.

Yolk-sac absorption and growth performance

Sampling for the yolk-sac started in 43 days for brook trout, in 36 days for Abant trout, and in 38 days for the hybrid (*S.t.a.*♀x*S.f.*♂). There are significant relationships among day and total length (Figure 1), total wet weight (Figure 2), dry larvae body weight (Figure 3), and dry yolk-sac weight (Figure 4) in brook trout, Abant trout, and hybrid larvae.The initial mean length of larvae was 14.95±0.45 mm in brook trout, 16.03±0.27 mm in Abant trout, and 13.12±0.86 mm in hybrids (P <0.05). It was measured as 21.58±1.33 mm, 22.56±0.75 mm, 22.11±1.10 mm at 28 days, and 34.10±2.85 mm, 32.33±1.58 mm and 32.26±2.62 mm at the end of 56 days, respectively (Figure 1) (Table 2).

At the beginning of the study, the mean total wet larval weight was measured as 53.18±1.79 mg in brook trout, 70.58±2.16 mg in Abant trout, and 62.56±6.25 mg in hybrids (P<0.001). Larvae wet weight was determined as 115.28±21.74 mg for brook trout, 115.37±8.80 mg for Abant trout,and 108.10±12.96 mg for hybrids on the 28th day, and 542.41±115.31 mg, 391.78±57.78 mg and 315.26±54.12 mg were measured, respectively on the 56th. day. (P<0.001) (Table 2). At the end of the study, the hybrid group was similar to Abant trout in terms of yolk-sac consumption (wet yolk-sac, dry-yolksac) at 0-28 days (Figure 4) and total wet larvae weight on the 56thday (P <0.05) (Figure 2).

Between 0 and 28 days, the K_D value was 2.24±0.05 in brook trout, 2.15±0.06 in Abant trout, and 2.15±0.07 in hybrids (P <0.05). YCR values were calculated as 0.36±0.05, 0.69±0.07 and 0.57±0.13 mg/day (P <0.001), and the water content(%) was calculated as 80.11±1.12, 81.60±0.63 and 82.39±1.58 (P

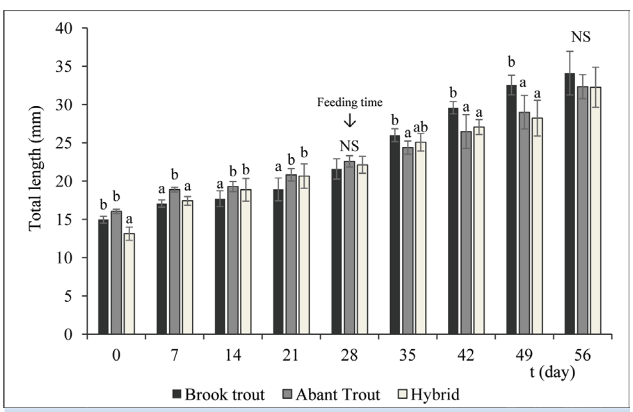

Figure 1. Growth in total length of brook trout, Abant trout, and their hybrid larvae (NS: Not significant (P>0.05); Different letters indicate statistical significance)

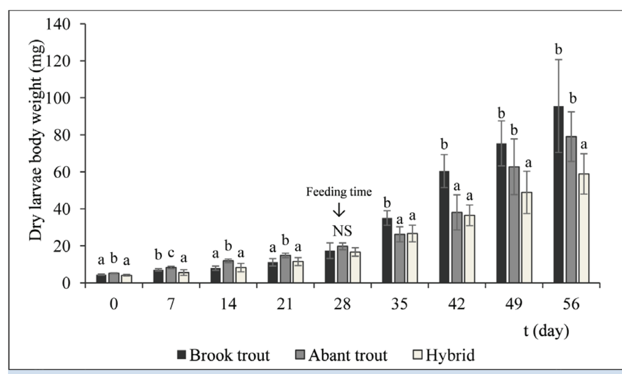

Figure 3. Dry body weight in brook trout, Abant trout, and their hybrid larvae(NS: Not significant (P>0.05); Different letters indicate statistical significance)

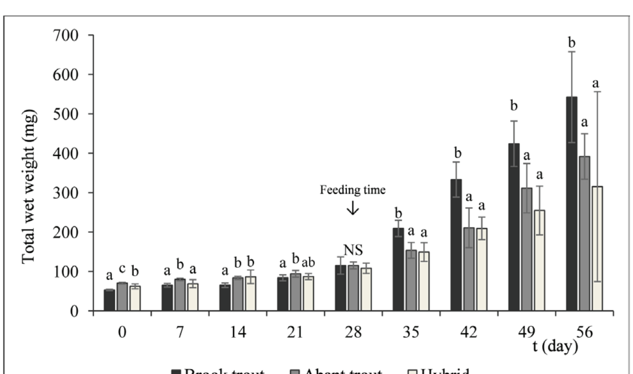

Figure 2. Total wet weight of brook trout, Abant trout, and their hybrid larvae (NS: Not significant (P>0.05); Different letters indicate statistical significance)

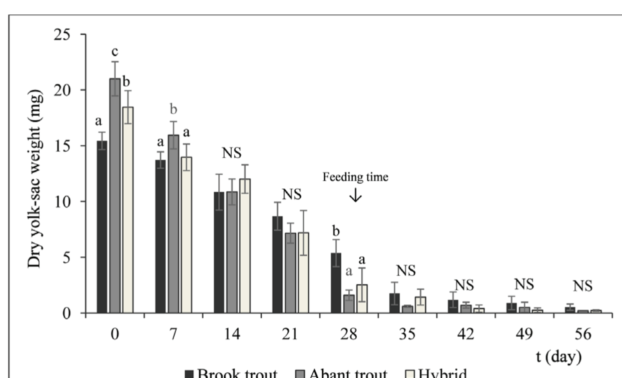

Figure 4. Dry yolk-sac weight in brook trout, Abant trout, and their hybrid larvae (NS: Not significant (P>0.05); Different letters indicate statistical significance)

<0.05), respectively. Development index and water content values in hybrids were similar to Abant trout, while YCR values showed differences in all groups.

The mean total larvae weights showed a difference on 0 (zero) day and 56th day (P <0.001). While there was no statistical difference in terms of specific growth and daily weight gain between 0 and 28 days, the difference was observed between 28 and 56 days, and the hybrids showed similarity with Abant trout. Hybrid fish were similar to Abant trout with the mean total weight, specific growth rate, and daily growth rate (Table 2).

The relationship between degree-days and length and dry yolk sac weight was linear and the relationship between degree-days and total wet weight and dry larvae body weight was exponential, and regression was highly significant between 0 and 28 days (Table 3).The P values in the y=a+bx equation do not support regression, so $y=ae^{bx}$ equation was used for wet weight and dry larvae body weight. This equation was found to be more accurate statistically. The sampling degree-days were 532, 581, 681, 813 and 923 in brook trout, 446, 500, 598, 724 and 832 in Abant trout and 472, 523, 621, 750 and 858 in hybrid, respectively.

DISCUSSION

The size, age, and genotypic structure of the fish have effective roles in egg size, and there are important variances between fish species in terms of egg productivity (Bromage et al., 1990; Bromage, 1995).

Table 2. Mean total length (mm), mean total weight (mg), specific growth rate (%day^{-1}), daily weight growth rate, and daily length growth rate values of brook trout, Abant trout, and their hybrid larvae

	Days	Brook Trout	Abant Trout	Hybrid	F	P
Mean total length (mm)	0	14.95±0.45^b	16.03±0.27^b	13.12±0.86^a	25.74	***
	28	21.58±1.33	22.56±0.75	22.11±1.10	1.82	*
	56	34.10±2.85	32.33±1.58	32.26±2.62	1.68	*
Mean total weight (mg)	0	53.18±1.79^a	70.58±2.16^c	62.56±6.25^b	19.41	***
	28	115.28±21.74	115.37±8.80	108.10±12.96	0.65	*
	56	542.41±115.31^b	391.78±57.78^a	315.26±54.12^a	18.71	***
Specific growth rate (% day^{-1})	0-28	2.76±0.90	1.76±0.35	1.95±0.66	2.93	*
	28-56	5.53±1.36^b	4.37±0.62^a	3.82±0.76^a	8.01	**
Daily weight growth rate	0-28	2.22±1.07	1.60±0.41	1.63±0.61	1.26	*
	28-56	15.25±4.78^b	9.87±2.22^a	7.40±2.03^a	15.19	***
Daily length growth rate	0-28	0.24±0.07	0.23±0.04	0.32±0.06	3.36	*
	28-56	0.45±0.14	0.35±0.08	0.36±0.12	2.14	*

*P>0.05; **P<0.05; ***p<0.001(Different letters indicate statistical significance)

Table 3. Relationship among degree-days and total length, total wet weight, drylarvae body weight, and dry yolk-sac weight

Treatment	Model	*a*	*b*	R^2	F value	p value
		Relationship between degree-days and total length				
Brook trout	$y=a+bx$	8.29	0.0139	0.71	107.00	<0.001
Abant trout	$y=a+bx$	11.31	0.0134	0.82	192.69	<0.001
Hybrid	$y=a+bx$	7.02	0.0181	0.72	107.63	<0.001
		Relationship between degree-days and total wet weight				
Brook trout	$y=ae^{bx}$	21.92	0.0017	0.77	147.12	<0.001
Abant trout	$y=ae^{bx}$	43.90	0.0011	0.82	189.47	<0.001
Hybrid	$y=ae^{bx}$	35.78	0.0013	0.59	60.80	<0.001
		Relationship between degree-days and dry larvae body weight				
Brook trout	$y=ae^{bx}$	1.14	0.0029	0.81	188.35	<0.001
Abant trout	$y=ae^{bx}$	1.81	0.0029	0.89	362.87	<0.001
Hybrid	$y=ae^{bx}$	0.84	0.0035	0.75	125.46	<0.001
		Relationship between degree-days and dry yolk-sac weight				
Brook trout	$y=a+bx$	27.81	-0.0241	0.88	308.44	<0.001
Abant trout	$y=a+bx$	38.99	-0.0450	0.94	702.69	<0.001
Hybrid	$y=a+bx$	34.46	-0.0369	0.89	353.83	<0.001

Based on linear regression; *a*, intercept; *b*, slope; *F value*, F statistic for testing the significance of the regression

It was reported that egg size of Abant trout is 5.01-5.20 mm (Uysal and Alpaz, 2003) and 4.91 mm (Kocabaş, 2011), and egg size of brook trout is 4.1-4.6 mm (Başçınar and Okumuş, 2004), 4.2 mm (Arıman, 2005), 4.3-4.9 mm (Başçınar et al., 2010) ve 4.49 mm (Serezli et al., 2010). Our results supported previous studies with 4.76 mm egg size of Abant trout and 4.11 mm egg size of brook trout.

Among the cultured fish species, Salmonids have a high egg and larval quality. The size of the egg is the most important criteria that reveals the quality of eggs and larvae (Bromage, 1995). The viable cell increase in fertilized eggs, embryonic development, larval and juvenile development periods may vary depending on the fish species, environment, and genetic factors (Uysal and Alpaz, 2003; Kocaman et al., 2009). In this study, the highest survival rate of larvae was observed in the Abant trout (*S.t.a.* ♀ x *S.t.a.* ♂) group and the lowest one was observed in the hybrid (*S.t.a.* ♀ x *S.f.* ♂) group (Table 1). Hybrid larvae have a lower survival rate than Abant and brook trout. Our results supported the previously performed hybridization studies with trout (Blanc and Chevassus, 1986; Aras et al., 2003; Başçınar et al., 2010; Akhan et al., 2011a). On the other hand, we could not get any results from the hybrid (*S.f.* ♀ x *S.t.a.* ♂) group. Similarly, the hybridization study was performed between Black Sea trout (*Salmo trutta labrax*, Pallas, 1811) and brook trout, but any eyed-egg and larvae were not seen from ♀ *S. fontinalis x* ♂ *S.t. labrax* (Başçınar et al., 2010). Many factors make hybridization failures such as the inability of sperm to enter the egg because of small micro-Pyle hole, sperm degeneration by egg cytoplasm without any function, ineffective fusing with the egg pronucleus, and many genetic factors (Yan and Özgünen, 1993).

At hatching, dry yolk-sac weight is determined as 15.44±0.78 mg (14.10-16.30) in brook trout, 21.00±1.54 mg (19.30-23.80) in Abant trout, and 18.46±1.48 mg (16.70-21.00) in the hybrid group (P <0.001). Similarly, dry yolk-sac weight at hatching was reported as 18.47±1.14 mg in Abant trout (Kocabaş et al., 2011), 23.33±0.59 mg (Başçınar et al., 2003), and 22.00±0.63 mg in brook trout (Önder et al., 2016), 27.8 mg in Atlantic salmon (Peterson and Martin-Robichaud, 1995), rainbow trout (*Salmo gairdneri*) 31 mg (Hodson and Blunt, 1986), and Black Sea trout 20.83 mg, brook trout 16.43 mg, and their hybrids 15.56 mg (Başçınar et al. 2010).

The length, total wet weight, dry body weight, and dry yolk-sac weights showed a significant relationship with the day in brook trout, Abant trout, and their hybrids (Figure 1-4). While the yolk-sac decreased (Figure 4), larva body weight increased (Figure 3). This result was similar to previous studies (Başçınar et al., 2003; Başçınar et al., 2005; Başçınar et al., 2008; Kocabaş et al., 2011; Önder et al., 2016; Başçınar and Sonay, 2016; Khan, 2019). Fish species, hatching time, hatch temperature, egg size, and broodstock feeding can cause differences in yolk-sac consumption (Başçınar et al., 2003; Dumas et al., 1995).

In order to determine the first feeding time in salmonid species, water content, behavioral criteria, temporal criteria, and morphological criteria are used (Peterson and Martin-Robichaud, 1995). For alevin, the most suitable first feeding time is when the maximum alevin reaches wet weight (Başçınar, 2010). When the maximum alevin weight is reached, the growth rate is zero, that is, the anabolic and catabolic rates become equal (Beer and Anderson, 1997; Başçınar et al., 2008). The energy, obtained by the absorption of the yolk-sac, cannot meet the needs after this period, so the weight of the alevin decreases. The development index value decreases and the water content of the alevin increases (Başçınar et al., 2008). Maximum alevin weight varies according to water temperature and egg size (Rombough, 1985). In previous studies, it was reported that when the alevin reached its maximum weight, the development index values were around "2". Development index values vary according to the water temperature (Başçınar et al., 2008). It was reported that the development index and water content for the first feeding of Atlantic salmon were 1.98 and 82-82,5% (Peterson and Martin-Robichaud, 1995), those for rainbow trout were 2.15 and 83.10% (Başçınar, 2010); that for Abant trout was 2.09 (Kocabaş et al., 2011); that for Black sea trout (*Salmo trutta labrax*) was 1.85-1.89 (Bascinar et al., 2008); that for Caspian brown trout (*Salmo trutta caspius*) was 2.05 (Kocabaş et al., 2012); those for brook trout were 1.88-1.94 (Önder et al., 2016) and 63.96-80.78% (Başçınar et al., 2003). In this study, K_D and water content values were determined as 2.24±0.05 and 80.11±1.12% in brook trout, 2.15±0.06 and 81.60±0.63% in Abant trout, and 2.15±0.07 and 82.39±1.58% in their hybrids.

According to growth parameters in the larval period, the lowest larval weight was determined in the brook trout on zero day. On 56th day, the hybrids had the lowest weight, and the brook trout had the highest weight (P <0.001). At the end of the study, the mean larval weights of the hybrids were similar to the Abant trout (Table 2). The maternal effects, egg size and quality, may have caused the difference in larval weight at the beginning of the study (Aras et al., 2003; Blanc et al., 2000). The results revealed that the brook trout made better use of feed. In the first feeding period, weight gain and specific growth rate were lower in hybrids and Abant trout than brook trout. The maternal effect and species difference may have caused that. In trout, water quality (temperature and oxygen), fish size (Austreng et al., 1987), feed quality, species, feeding style, and genetic line of fish are the main affecting factors of good feed intake, feed conversion, and growth (Sonay and Başçınar, 2017).

CONCLUSION

In conclusion, it was observed that the hatching efficiency of the hybrid (female Abant trout and male brook trout) was similar to the brook trout; however, the growth performance of the hybrid was similar to the Abant trout. In addition, the hatching and early development stages (from hatching to free-swimming stage) of brook trout, Abant trout, and their hybrids were determined. In the early development period, the relationship between yolk-sac consumption and growth was shown. These results can be used in the development of hatchery management programs and in future studies.

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CONFLICT OF INTEREST

There is no conflict of interest to report.

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