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The influence of stocking density on growth performance, feed intake and production of common carp, *Cyprinus carpio* L., at one summer of age, in ponds aquaculture systems

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Abstract. The paper presents some aspects regarding the influence of stocking density on common carp (*Cyprinus carpio*) fry and fingerlins, fed with extruded and expanded pellets. The experiment covered a 150 day-period, and was made in four small breeding units, type pond, 6000 m^2 each. Two kind of stocking density variants were compared, with repetition: V1, with 30000 fish ha^{-1} (30 kg ha^{-1}) and V2, with 15000 fish ha^{-1} (15 kg ha^{-1}), respectively. The growth parameters (FBG, GR, SGR, FCR) at the end of the experiment, revealed that the mean biomass gain in V1 was 4295 kg ha^{-1} compared to 2275 kg ha^{-1} in V2. This was nearly perfectly correlated with the stocking density. The mean growth rate (GR) of fish biomass varied in a similar way, from 28.63 kg day^{-1} in V1 to 15.17 kg day^{-1} in V2. The mean specific growth rate (SGR) of fish biomass was 3.31% day^{-1} in V1 and 3.35% day^{-1} in V2. This shows that the fish growth was very good. The mean feed conversion ratio (FCR) was 1.41 kg of pellets/kg weight gain in V1 and 1.33 kg of pellets/kg weight gain in V2. The parameters of fish growth performance showed that variation in stocking density did not negatively influence the fish production, the common carp having a very good growth rate. An increase of fish biomass is possible if pellets with a moderate level of crude protein (30%) are used.

Key Words: common carp juveniles, extruded/expanded pellets, water quality, feed efficiency.

Introduction. Common carp (*Cyprinus carpio* L.) is the oldest cultured and the most domesticated fish species of the world (Flajšhans & Hulata 2007; Lehoczky et al 2005; Balon 1995). In Central–Eastern Europe, Romania is one of the traditional common carp and chinese carp producing countries, with more then 10000 metric tons $year^{-1}$ (FAO 2015).

Stocking density is an important factor to be considered in fish aquaculture. It is widely accepted that inadequate stocking density is one of the main factors that restricts the growth and survival of fish species in different culture systems. Growth performance is probably one of the most well studied physiological parameters related to aquaculture research (De las Heras et al 2015). Survival and production of fry and fingerlings in ponds system depend on stocking density also, type and quality of fertilizers and supplementary feeds (Chakraborty & Mirza 2007; Drew et al 2007).

High biomass could activate stress response affecting negatively the final fish production, while low stocking densities could suppose, due to an inadequate use of space, higher production costs and lower profitability for the industry. Moreover, under intensive fish culture systems, high stocking densities together with insufficient water renovation in the rearing units could decrease water quality, compromising the growth of fish (Pickering 1990; Ruane et al 2002; De las Heras et al 2015).

This study aimed to evaluate the effect of different stocking densities on common carp fry and juveniles growth performance and feed efficiency.

Material and Method

Study site and pond preparation. The 5 months experiment was conducted between June and November 2014 in four small ponds - V1R1(BR1), V1R2(BR2), V2R1(BR3), V2R2(BR4)-, located at the Giurgiu/Bila Fish Farming of Alexander Park Company. All ponds were rectangular in shape with a size of 6000 m^2 and an average depth of 1.2 m. Prior to the experiment, ponds were drained, renovated, small fishes (*Leucaspius delineatus, Pseudorasbora parva, Gobio gobio, Carrasius gibelio, Perca fluviatilis, Rutilus rutilus, Scardinius erythrophthalmus* etc.) and macro vegetation (*Phragmites communis, Tipha latifolia*) were eradicated.

In order to increase the natural food growth and availability, 100 kg ha^{-1} $CaOCl_2$ (bleach), 1000 kg ha^{-1} $Ca(OH)_2$ (lime), 100 kg ha^{-1} NH_4NO_3 (ammonium nitrate) and 3000 kg ha^{-1} manure were used.

Fish stocking and feed management. All ponds were stocked with common carp fry, at 1 g/fish body weight. Two kind of stocking density variants were compared: V1, with 30000 fish ha^{-1} (30 kg ha^{-1}) and V2, with 15000 fish ha^{-1} (15 kg ha^{-1}), respectively. Both treatments were executed in duplicate. As food, in V1 and V2, was used the same supplementary feed. During the first 30 days, in V1 and V2, were used similar ratios and the same extruded pellets with 48% crude protein, type FeedEx 48/10. After that, during the last 120 days was used expanded pellets with 30% crude protein, type FeedEx C 30/07 Standard. The pellets were imported by Kralex Food Solutions Technology Co, Romania from ECO FEED D.O.O., Serbia (Table 1).

Table 1

Chemical composition of pellets

Nutrients	*UM*	*FeedEx 48/10*	*FeedEx C 30/07 Standard*
Crude protein	%	48.0	30.0
Crude fat	%	10.0	7.0
Ash	%	8.0	10.0
Crude cellulose	%	4.0	4.0
Phosphorus	%	0.8	0.8
Vitamin A	U.I. kg^{-1}	10000	10000
Vitamin D_3	U.I. kg^{-1}	1800	1800
Vitamin E	mg kg^{-1}	60.0	60.0
Copper	mg kg^{-1}	30.0	30.0
Antioxidant BTH E_{321}	mg kg^{-1}	100	100
Crude energy	Mj kg^{-1}	19.4	18.1
Metabolic energy	Mj kg^{-1}	15.3	14.5
Granulation	mm	0.2	2.0

As feed ingredients, the two kind of diets contained fish meal, soybean meal, cereals products, yeast, minerals and vitamin premix. The food was applied daily, at 25% feeding level in the first week to 0.75% in the last week. Feeding rates per pond were adjusted weekly after weighting minimum 100 fish.

Water quality assessment. From each pond, water samples for analysis were colected daily, for temperature, dissolved oxigen and pH mesurements. The instruments used were a thermometer/pH-meter HI 98128 and an oxygenmeter HI 9147, from Hanna Instruments Co.

Fish harvesting. At the end of the experiment, ponds were drained and all fish were harvested and weighted as total biomass. For each variant, mean final body weight was estimated based on 50 samples, multiplied by 120 fish/sample (n = 6000 fish/pond). The technologiocal indicators was calculated using the formulas:

Fish biomass gain (FBG): $FBG = (Bf) - (Bi)$ [kg ha^{-1}]
with Bf – final fish biomass; Bi – initial fish biomass

Growth rate (GR): $GR = (Bf - Bi)/t$ [kg fish biomass day^{-1}]
with Bf – final fish biomass; Bi – initial fish biomass, t - duration of the experiment

Specific growth rate (SGR): $SGR = 100 * (\ln Bf - \ln Bi)/t$ [% fish biomass day^{-1}]
with Bf – final fish biomass, Bi – initial fish biomass, t - duration of the experiment

Feed conversion ratio (FCR): $FCR = F/FBG$ [kg feed intake per kg fish biomass gain]
with F – feed intake, FBG – fish biomass gain

Statistical analysis. The mean values for growth and water quality parameters from different treatments were tested using ”student t test” for independent samples respectively Kruskal-Wallis non parameter test (measurement variable does not met the normality assumption). Standard deviation in each parameter and treatment was calculated and expressed as „mean±SD”. Mean differences were considered significant at $p < 0.05$. All statistical analyses were performed with the aid of a computerized statistical package, „SPSS for Windows” version 21.0.

Results and Discussion

Water quality assessment. The environmental parameters have an immense influence on the maintenance of a healthy aquatic environment and production of food organisms. Growth and feed consumption of fish are normally governed by a few environmental factors like water temperature, dissolved oxigen, pH, conductivity, nitrogen compounds etc. (Flajšhans & Hulata 2007).

The temperature recorded during the experiment, was, most often, within the optimum range for growth of carp juveniles (20-27^{o}C), with some exceptions, in autumn when dropped below 15^{o}C (Figure 1). In the four experimental ponds, water temperature registered similar dynamics with no statistical differences ($p > 0.05$) among mean values (17.32±1.27^{o}C in V1R1; 17.30±1.27^{o}C in V1R2; 17.29±1.28^{o}C in V2R1; 17.23±1.30^{o}C in V2R2).

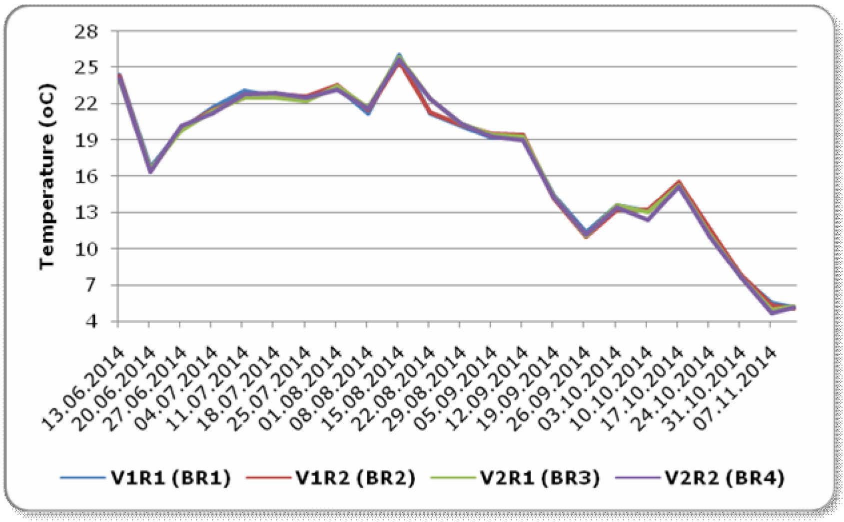

Figure 1. Water temperature dynamics.

The water dissolved oxygen, in all cases, fluctuated within the range 6.0 mg L^{-1} (July, August) and 8.9 mg L^{-1} (September, October and November), optimal values for carp breeding (Figure 2). The statistical comparisons of mean values of dissolved oxygen measured in all four ponds (7.30±0.18 mg L^{-1} in V1R1, 7.27±0.19 mg L^{-1} in V1R2, 7.23±0.18 mg L^{-1} in V2R1, 7.28±0.17 mg L^{-1} in V2R2) showed no significant differences ($p > 0.05$) among treatments.

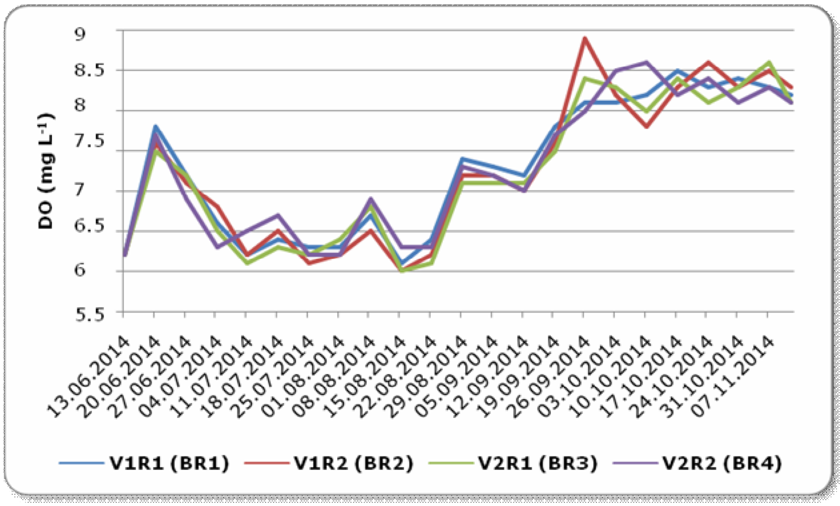

Figure 2. Dissolved oxigen dynamics.

The third parameter to follow, water pH, oscillated around minimum values of 7.2 units in June and the first half of July, and maximum values of 8.5-8.6 pH units at late July, August and September. Along with water cooling, in October and November, the pH has stabilized around optimum of 7.5 units (Figure 3). In order to avoid unpleasant surprises in the hottest months, July and August, the water was aerated by means of electrically operated aerators. The statistical comparisons of mean values of pH measured in all four ponds (7.83±0.02 in V1R1, 7.87±0.02 in V1R2, 7.84±0.02 in V2R1, 7.83±0.02 in V2R2) showed no significant differences ($p > 0.05$) among treatments.

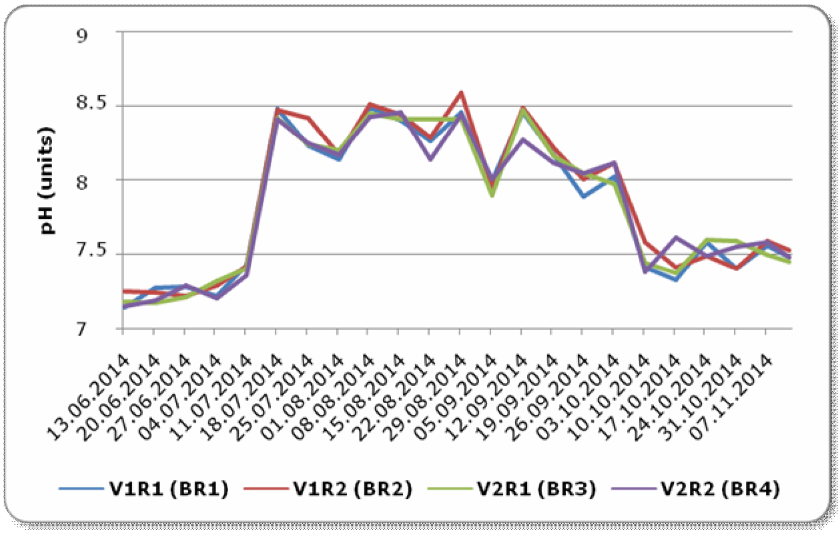

Figure 3. Water pH dynamics.

Growth performance of fish. Different authors indicated for some species that growth is density dependent and that there is an inverse relationship between stocking density and individual size of fish produced, primarily because the food supply has to be shared between individuals (Holm et al 1990; Christiansen et al 1992; Sharma & Chakrabarti 1998, 1999; Ruane et al 2002; Chakraborty & Mirza 2007; Yang et al 2011; Enache et al 2011).

The influence of stocking density on growth performance of one summer common carp can be analysed using some technological parameters (Table 2).

Table 2

Growth performance of one summer common carp

Indicators	*Experimental variant*					
	V1			*V2*		
	V1R1 (BR1)	*V1R2 (BR2)*	*MEAN*	*V2R1 (BR3)*	*V2R2 (BR4)*	*MEAN*
Initial fish biomass (kg ha^{-1})	30.00	30.00	30.00	15.00	15.00	15.00
Final fish biomass (kg ha^{-1})	4350.00	4300.00	4325.00	2253.00	2328.00	2290.50
Fish biomass gain (kg ha^{-1})	4320.00	4270.00	4295.00	2238.00	2313.00	2275.50
Initial number of fish (fish ha^{-1})	30000	30000	30000	15000	15000	15000
Final number of fish (fish ha^{-1})	20327	14930	17628	6997	6275	6636
Survival (%)	68.00	50.00	59.00	47.00	42.00	44.00
Initial mean body weight (kg fish^{-1})	0.001	0.001	0.001	0.001	0.001	0.001
Final mean body weight (kg fish^{-1})	0.214	0.288	0.251	0.322	0.371	0.346
Individual weight gain (kg fish^{-1})	0.213	0.287	0.250	0.321	0.370	0.345
Experiment duration (days)	150	150	150	150	150	150
Growth rate (GR) (kg fish biomass day^{-1})	28.80	28.47	28.63	14.92	15.42	15.17
Specific growth rate (SGR) (% fish biomass day^{-1})	3.32	3.31	3.31	3.34	3.36	3.35
Food quantity intake (kg)	6057.00	6057.00	6057.00	3028.00	3028.00	3028.00
Feed conversion ratio (FCR) (kg kg^{-1})	1.40	1.42	1.41	1.35	1.31	1.33
Feed crude energy (Mj kg^{-1})	19.40/ 18.10	19.40/ 18.10	19.40/ 18.10	19.40/ 18.10	19.40/ 18.10	19.40/ 18.10
Feed metabolic energy (Mj kg^{-1})	15.30/ 14.50	15.30/ 14.50	15.30/ 14.50	15.30/ 14.50	15.30/ 14.50	15.30/ 14.50
Feed crude protein (%)	48.00/ 30.00	48.00/ 30.00	48.00/ 30.00	48.00/ 30.00	48.00/ 30.00	48.00/ 30.00

During the experimental period, increases in both body weight and fish biomass for the two experimental stocking densities were detected. After 150 days, at the end of our trial, an inverse pattern of changes in individual body weight was also observed with respect to stocking density (Figure 4).

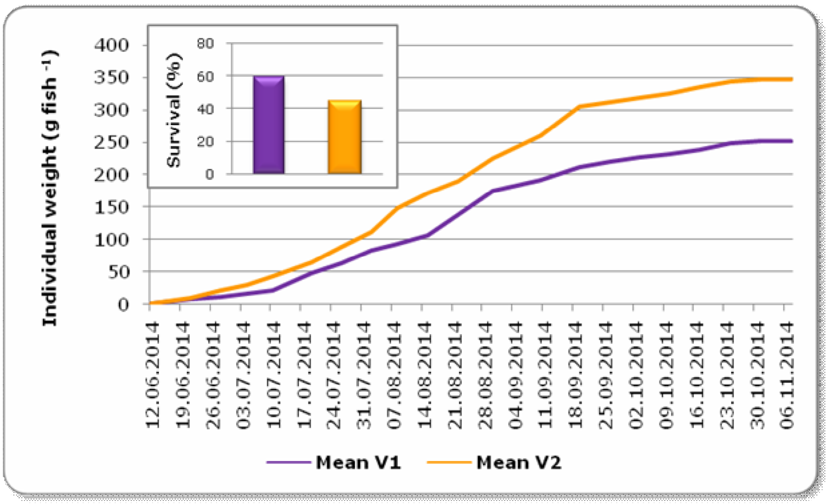

Figure 4. Individual mean body weight gain and survival of fish.

The fish survival was likewise influenced by the stocking density, in V2 variant the mortality exceeding the threshold of 50% with 6% (survival rate was 44%) while in V1 variant the survival rate was 59%. The fish from V2 variant, where the stocking density was lower (15000 fish ha^{-1}), showed a higher mean body weight (treatment mean 0.346±0.02 kg kg fish^{-1}), comparing with the fish from the V1 variant, within twice higher stocking density variant (30000 fish ha^{-1}), were the mean final body weight was lower (treatment mean 0.251±0.03 kg kg fish^{-1}).

Statistic comparison of the mean final fish weight (Kruskal-Wallis test) revealed significant differences ($p < 0.01$) among groups (both trials and replicates), post hoc test emphasizing distinct groups of individuals based on their weight. Thus, in V1R1 variant, the mean individual final weight was 0.21±0.003 kg kg fish^{-1}, in V1R2 0.29±0.002 kg kg fish^{-1}, in V2R1 0.32±0.002 kg kg fish^{-1} and in V2R2 0.37±0.003 kg kg fish^{-1}. These results indicate the fact that, beside density, there are other factors influencing growths, most probably related to the pond particularities and natural food availability.

Regarding the fish biomass, the growth parameters revealed that the mean biomass gain in V1 was 4295 kg ha^{-1} compared to 2275 kg ha^{-1} in V2. This was direct correlated with the stocking density. The mean growth rate of fish biomass (GR), varied in a similar way, from 28.63 kg day^{-1} in V1 to 15.17 kg day^{-1} in V2 (Figure 5).

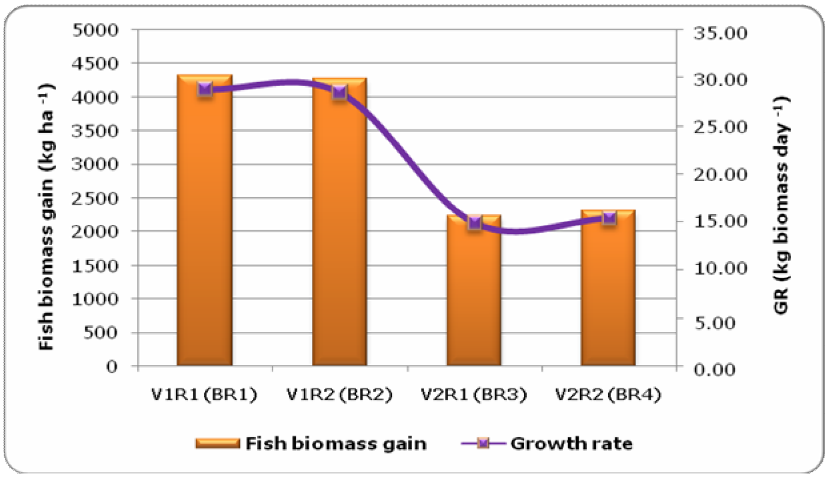

Figure 5. Fish biomass gain and growth rate.

The mean specific growth rate of fish biomass (SGR), was 3.31% day^{-1} in V1 and 3.35% day^{-1} in V2, while the mean feed conversion ratio (FCR), was 1.41 kg of pellets/kg weight gain in V1 and 1.33 kg of pellets/kg weight gain in V2 (Figure 6). These results show that in terms of growth rate and feeding efficiency there were some slightly differences between the two variants but with no major impact on the final resuls when reporting to the high density tested in the V1 variant.

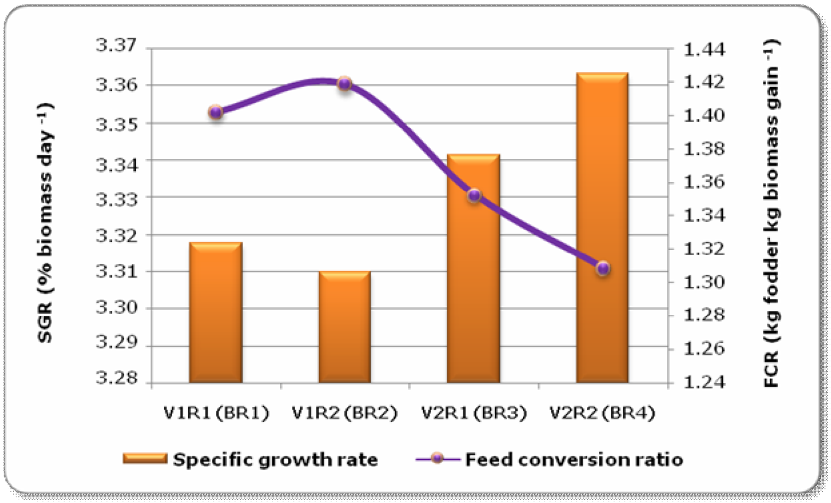

Figure 6. Specific growth rate and feed conversion ratio.

In terms of SGR, our results are in accordance with those found by other authors. For example, De Silva & Davy (2010), stated that SGR of fish fed on high protein and energy diet shows higher value, but fish fed on supplementary feeds made on farm shows SGR value of 3-4% day^{-1}.

In general, in conventional earthen ponds, where fish are fed with supplementary feeds and without supplemental aeration, are reported productions limited to 2000 to

4000 kg ha^{-1} because of the limited availability of suitable nutritional inputs (Rahman et al 2006; Bosma & Verdegem 2011). In Romania the average individual weight for one summer carp is 60-100 g fish^{-1} (MAIA-DIA 1985). The present study showed possible a production exceding 4 t ha^{-1} and an individual body weight higher then 200 g fish^{-1} (for 30000 fish ha^{-1} density) and higher then 300 g fish^{-1} (for 15000 fish ha^{-1} density).

Conclusions. Physiological responses to different stocking densities and their subsequent effects on growth rate and feed efficiency were assessed on common carp fry and juveniles.

The results show that individual growth processes in common carp slightly decreased when stocking density was increased. In this regard, the best individual fish growth were observed at the lowest stocking density of 15000 fish ha^{-1}. But, in term of fish biomass gain, the parameters of fish growth performance showed that variation in stocking density, to 30000 fish ha^{-1}, positively influences the ponds production. Obtaining a mean body weight over 300 g individual^{-1} in the first summer is a premise for fast growth in the second summer when carp could quickly reach the table size.

Finally, it can be concluded that the survival, fish biomass gain and production of one summer common carp were direct related to the stocking densities, the variant with 30000 fish ha^{-1} may be advisable for rearing.

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