

THE EFFECT OF CHEMICAL AND ORGANIC FERTILIZATION ON PHYTOPLANKTON AND FISH PRODUCTION IN CARP (CYPRINIDAE) POLYCULTURE SYSTEM

EL EFECTO DE LA FERTILIZACIÓN QUÍMICA Y ORGÁNICA SOBRE EL FITOPLANCTON Y LA PRODUCCIÓN DE PECES EN UN SISTEMA DE POLICULTIVO DE CARPAS (CYPRINIDAE)

Ponce-Palafox JT¹, Arredondo-Figueroa JL^{2,3}, Castillo-Vargasmachuca SG¹, Rodríguez Chávez G¹, Benítez Valle A¹, Regalado de Dios MA¹, Medina Carrillo F¹, Navarro Villalobos R¹, Gómez Gurrola JA¹, López Lugo P¹.

¹Universidad Autónoma de Nayarit. Unidad Académica de la Escuela Nacional de Ingeniería Pesquera. Unidad de Bioingeniería Costera. Bahía de Matanchén Km. 12, Carretera a los Cocos. San Blas, Nayarit. México. C.P. 63740. ²Posta Zootécnica, Departamento de Zootecnia, Centro de Ciencias Agropecuarias,

³Universidad Autónoma de Aguascalientes, Jesús María, Apartado Postal 3, C.P. 20900, Aguascalientes, Aguascalientes.

Abstract

This study reports the effects of sheep and pig liquid manure, and chemical fertilizer on the phytoplankton, primary productivity and aquaculture production in the cultivation of carp in semi-rustic ponds. The total yield was 4.632 kg in two hectares. Treatment with chemical fertilizers was found to present the highest yield with 10.06 ± 0.67 (kg/Ha/day), followed by treatment with pig manure (8.27 ± 1.24 kg/Ha/day) and sheep manure (6.33 ± 1.95 kg/Ha/day). It was also found that concentrations of phytoplankton were significantly ($p < 0.05$) higher in ponds fertilized with sheep and pig manure (945,940 and 1,157,706 cells/ml, respectively) than in ponds where chemical fertilizer was used (744,560 cells/ml). In general, conditions were adequate to obtain high yields without commercial feed, thus organic fertilizer application can be recommended because of its availability and low cost.

Keywords: polyculture, fertilization, manure, water quality, carp.

Resumen

Se estudiaron los efectos del abono líquido de borrego y cerdo, y un fertilizante químico, sobre el fitoplancton, la productividad primaria y la producción acuícola en el cultivo de carpas en estanques semirústicos. El rendimiento total fue de 4,632 kg en dos hectáreas. Se encontró que el tratamiento con fertilización química presentó el mayor rendimiento con 10.06 ± 0.67 (kg/Ha/día), seguido por tratamiento con abono de cerdo (8.27 ± 1.24 kg/Ha/día) y el de borrego (6.33 ± 1.95 kg/Ha/día). También, se encontró que en los estanques fertilizados con abono de borrego y cerdo se presentaron las concentraciones de fitoplancton (945,940 y 1,157,706 cells/ml, respectivamente) significativamente ($p < 0.05$) más altas que en los estanques donde se aplicó fertilización química (744,560 cells/ml). Las condiciones en general fueron adecuadas para obtener altos rendimientos sin alimentos comerciales y la aplicación de abonos orgánicos puede ser recomendada debido a su disponibilidad y bajo costo.

Palabras clave: policultivo, fertilización, abonos, calidad del agua, carpa.

Corresponding Author:

Ponce Palafox J. T., Universidad Autónoma de Nayarit. Unidad Académica de la Escuela Nacional de Ingeniería Pesquera. Unidad de Bioingeniería Costera. Bahía de Matanchén Km. 12, Carretera a los Cocos. San Blas, Nayarit. México. C.P. 63740. Teléfono y Fax: (323)2312120. Correo electrónico: jesus.ponce@usa.net

Introduction

Fish culture with manures as the main nutritional input is a long-time practice in China (Tang, 1970). Nevertheless the wide use of mineral fertilizers in industrialized countries; those are supply limited and even expensive in many low developed nations. Animal manures, which are generally plentiful worldwide, constitute a low- to intermediate-cost nutrient source. The study of fertilization in the carp polyculture has focused to address issues about the effect of chemical and organic fertilization on water quality and growth of carp (Olah, 1986; Ponce-Palafox *et al.*, 1994; Vromant *et al.*, 2002; Dhawan, 2002), the water quality and fish production in ponds with organic fertilization and no fertilization (Nikolova *et al.*, 2008a, 2008b) and the effect of supplemental feeding on water quality and structure of phytoplankton in ponds fertilized with tilapia and carp (Abdel-Tawwab *et al.*, 2007).

The first link in food chains inland waters are phytoplankton and are an indicator of production level. Within these environments, ponds fish with a high abundance characterized as highly eutrophic systems primary productivity, and promote the growth of fish in a polyculture fish, particularly filters. In ponds fertilized phytoplankton increase is due to the intensity and type, as productivity increases with careful management, with a continuous and controlled addition of inorganic and / or organic fertilizers to produce autotrophic organisms. (Hepher and Pruginin, 1981)

There have been several works research regarding the development of phytoplankton, was described some effects of

different types of fertilizers in ponds its composition, growth, relationships between groups and their dynamics in daily fluctuations and monthly, indicating that they depend of various factors, including predation, the incidence light and nutrient type (O'Brien and Noyelles, 1974; Schroeder 1975; Almazan and Boyd, 1978, Wilkins and Piedrahita, 1988; Moustaka and Nikolaidis, 1992; Vadas, 1992). It is important to the understanding of diversity wealth, other characteristics of phytoplankton and the function performed by the channels trophic polyculture systems. In Mexico, works on the issues are few and far between, therefore carried out this work with In order to estimate some effects on their abundance and composition of three fertilizer treatments: organic, inorganic and mixed pond polyculture of fish. In the present study, the effects of manures and mineral fertilizer on phytoplankton and fish production were evaluated in ponds stocked with carp polyculture.

Materials and methods

This work was carried out at the integrated fish farm in Hidalgo State, Mexico (20°11'56.99"N; 99°16'53.10"O; 1,966 m.a.s.l.). Nine ponds (Fig.1) with surface area 0.14 to 0.45 Ha were used in this study. Each pond was stocked with five species: grass carp *Ctenopharyngodon idella* (50%), silver carp *Hypophthalmichthys molitrix* (2%), bighead *Aristichthys nobilis* (15%), bream carp *Megalobrama amblycephala* (13%) and mirror carp *Cyprinus carpio specularis* (20%), at one stocking rate (15,000 fishes/Ha), for a duration of 300 days. The reference values were according to the experience made on the farm for several years marked by aquaculturists.



Figure 1. Integrated fish farm polyculture in Tezontepec de Aldama, Hidalgo State, Mexico. (20°11'56.99"N; 99°16'53.10"O; 1,966 m.a.s.l.).

These fish ponds (Fig. 1) received liquid sheep manure (2,6,9 ponds), liquid pig manure (1,3,8 ponds) and mineral fertilizer (urea and triple superphosphate) (4,5,7 ponds) at daily intervals; volumes of manure used were 1.7 to 3.5 m³/Ha/day (34.0 to 70.0 kg dry matter/Ha/day). The ponds were assigned to each treatment in a randomized design with three replicates per treatment. At the outlet of each pond were determined variables of water quality and productivity. Water dissolved oxygen (mg/L) and ammonium (mg/L) concentration were measured every 15 days. Primary productivity, gross primary, respiration and phytoplankton were measured every 30 days using the procedures outlined by Boyd (1990) and Arredondo-Figueroa and Ponce-Palafox (1998). Values for fish yield and biomass were determined for each pond, following EIFAC (1980) guidelines. Analysis of variance was used to detect significant differences in biological factors between treatments. Treatments were compared using

the Tukey's test. The analyses were done using SPSS 10.0 for Windows package.

Results and discussion

The study was carried out in average water temperature of 23 °C, which is within the range of studies in the region of 22 to 25 °C. The carp need at least 18 °C minimum temperature for growth (Arredondo-Figueroa and Juarez, 1986), so there was no negative effect on the growth of polyculture. After temperature, dissolved oxygen concentration of water is the most important variable in a pond culture system (Arredondo-Figueroa and Ponce-Palafox, 1998). The concentration of this variable was 8.8 to 10.4 mg/L throughout the culture (Table 1). This concentration of dissolved oxygen in water is found above the minimum reported for these species (3.25 mg/L) in the region by Gonzalez *et al.* (2002), without affecting the growth of carp.

Table 1. Water quality and productivity data in carp polyculture.

Parameter	Sheep manure	Pig manure	Mineral fertilizer
Temperature (°C)	23.2±2.2	23.4±2.1	23.1±1.5
Dissolved Oxygen (mg/L)	8.8±3.9 ^a	9.9±4.5 ^a	10.4±2.5 ^a
Ammonium (mg/L)	0.03±0.09 ^a	0.08±0.13 ^a	0.04±0.10 ^a
Primary Productivity (gC/m ³ /h)	0.83±0.55 ^a	0.89±0.74 ^a	0.75±0.70 ^a
Gross primary (gC/m ³ /h)	0.95±1.17 ^a	1.01±1.16 ^a	0.96±1.32 ^a
Respiration (mgO ₂ /L)	0.24±0.33 ^a	0.26±0.22 ^a	0.29±0.42 ^a

Means in the same row with different superscripts are significantly different at $p < 0.05$

There have been studies on carp polyculture in extensive systems in central Mexico, where densities have been used 5,000-9,000 org/Ha (Navarrete *et al.*, 2000), it was decided to use a semi -Intensive pond density of 15,000 org /Ha. In addition to previous tests performed in fish ponds of “Granja Experimental de Policultivo de Peces” in Tezontepec de Aldama, Hidalgo, Mexico, used for this study determined the density selected.

The phytoplankton, productivity and respiration were representative for the open waters of the whole ponds. Chlorophytes were the dominant phytoplankton group in the culture ponds throughout the experiment, followed by the Bacillariophytes and Cianophytes (Table 2). Padmavathi and Prasad (2009) in carp ponds in India found that the major groups of phytoplankton present were also those reported in this study. There was high concentration of Cianophytes, Chlorophytes and Bacillariophytes in pig manure, and Chlorophytes in sheep manure and mineral fertilizer. Phytoplankton was represented by 40 genera, 16 of which were found more frequently in the system. Debeljak and Adamek (1994) found that the structure of phytoplankton in fish ponds with the poultry fertilizer made up 131 species, and in the fish ponds treated with the mineral fertilizer 105 species. Relative abundance changed with time, with Chlorophytes being the dominant species in the winter and Bacillariophytes and Cianophytes in the warm season. The dominant species was Chlorophytes with significant difference ($p < 0.05$).

Table 2. Phytoplankton groups (cells/mL) on carp ponds.

Group	Sheep manure	Pig manure	Mineral fertilizer
Cianophytes	178,950 ^b	255,200 ^a	132,440 ^c
Chlorophytes	660,690 ^a	225,990 ^b	284,170 ^b
Euglenophytes	59,050 ^b	175,050 ^a	154,650 ^a
Bacillariophytes	259,016 ^a	289,700 ^a	173,300 ^b
Total	1,157,706 ^a	945,940 ^a	744,560 ^b

Means in the same row with different superscripts are significantly different at $p < 0.05$

Diversity index fluctuated between 0.25 to 5.6 bits, which corresponds to an increase in the available niches in the warm season and characteristic of eutrophic waters with high productivity. These conditions seem to be good for the growth of fish species, especially for the filter-feeding ones. It was found that in ponds fertilized with sheep manure and pig showed concentrations of phytoplankton (945,940 and 1,157,706 cells/ml, respectively) significantly ($p < 0.05$) higher than in ponds where chemical fertilizer was applied (744.560 cells/ml). These concentrations of phytoplankton are higher than those reported by Molina-Astudillo *et al.* (2003) in carp ponds which manure using cow (17,008 to 630,731 cells/ml).

Respiration was evaluated by means of light and dark bottles, with an average value from 0.24 to 0.29 mgC/L/three hours (25% gross photosynthesis). Respiration had a similar tendency in animal manure treatments.

Gross photosynthesis maintained an increasing tendency of 0.95 to 1.0 mgC/L /three hours and primary productivity with values between 0.75 and 0.89 mgC/L/three hours. Primary productivity revealed a differential pattern between organic manures and mineral fertilizers. There are no publications on the production-respiration in carp polyculture ponds.

The yield of carp was significantly more in mineral fertilizer ponds (10.06 kg/Ha/day) than in pig (8.27 kg/Ha/day) and sheep (6.33 kg/Ha/day) manure ponds (Table 3). In general, the final biomass obtained from 458.4 to 577.6 kg is within that reported by Gonzalez *et al.* (2002) of 540 kg for carp polyculture without supplemental feed.

Table 3. Production, yield and survival data in carp polyculture.

Parameter	Sheep manure	Pig manure	Mineral fertilizer
Surface area (m ²)	2,228±250 ^a	2,069±210 ^a	1,970±180 ^a
Biomass initial (kg)	6.40±1.82 ^a	6.89±1.44 ^a	7.19±1.3 ^a
Biomass final (kg)	474.8±193.4 ^a	458.4±133.3 ^a	577.6±85.7 ^a
Fish yield (kg/ Ha/ day)	6.33±1.95 ^a	8.27±1.24 ^a	10.06±0.67 ^b
Survival (%)	73.5±18.1 ^a	81.4±9.0 ^a	81.7±6.0 ^a

Means in the same row with different superscripts are significantly different at $p < 0.05$

Added manure or fertilizer had a positive effect (Vromant *et al.*, 2002) on the dissolved oxygen, phytoplankton and primary productivity. All the treatments did not degrade the physico-chemical properties of water (Ponce-Palafox *et al.*, 1994). The liquid sheep manure and liquid pig manure cause wide fluctuations in the water quality, mainly dissolved oxygen concentration which is shown in the largest standard deviations of 3.9 and 4.5 (mg/L) for sheep and pig, respectively, and lower in the mineral fertilizer (2.5 mg/L). The ammonium it was significantly higher in the mineral fertilizer. Information about the potential production level of a fertilized fishpond is indispensable for its rational management. From the data collected by Barbe *et al.* (1999) statistical treatment evidenced relationships between phytoplankton types, chlorophyll

densities and fish production levels. Combining both five typical groups of phytoplankton and five different concentrations of chlorophyll a arranged into a grid, it was possible to determine the potential fish production of the ponds (up to over 500 kg/Ha).

In general, an inverse relationship was found between the abundance of phytoplankton and fish yield and a direct relationship between yield and concentration of dissolved oxygen of pond water. The general conditions were adequate to obtain high yields without commercial feeds (2.0 ton/Ha), higher than those found in temperate regions (0.72 ton/Ha) of Europe (Nikolova *et al.*, 2008a) and the application of organic manures can be recommended because of their availability and low cost.

Bibliographical References

- Abdel TM, Abdelghany AE, Ahmad MH. Effect of diet supplementation on water quality, phytoplankton community structure, and the growth of Nile tilapia, *Oreochromis niloticus* (L.), common carp, *Cyprinus carpio* L., and silver carp, *Hypophthalmichthys molitrix* V. polycultured in fertilized earthen ponds. *J Appl Aquaculture* 2007; 19: 1-24.
- Almazán G, Boyd CE. An evaluation of secchi disk visibility for estimating plankton density in fish ponds. *Hydrobiologia* 1978; 65: 601-608.
- Arredondo JL, Juarez R. *Ciprinicultura. Manual para el cultivo de Carpas*. México, D.F. Secretaría de Pesca 1986. 121.
- Arredondo JL, Ponce JT. *La calidad del agua en acuicultura: Conceptos y Aplicaciones*. México D.F.: AGT Editors. S.A. 1998. 250.
- Barbe J, Schlumberger O, Bouretz N. Utilisation du phytoplancton pour estimer la production piscicole potentielle des étangs. *Bulletin Francais de la Peche et de la Pisciculture* 1999; 355: 387-402.
- Boyd CE. *Water quality in ponds for aquaculture*. Birmingham Alabama: Birmingham Publishing Co. 1990. 482.
- Debeljak L, Adamek Z. Utjecaj gnojidbe na razvoj fitoplanktona u saranskim mladincjacija. *Ribarstvo* 1994; 52: 3-16.
- Dhawan A, Kaur S. Pig dung as pond manure: Effect on water quality, pond productivity and growth of carps in polyculture system. *Naga [Naga ICLARM Q.]* 2002; 25: 11-14.
- EIFAC. European Inland Fisheries Advisory Commission. Report of a study group on the standardization of methodology in fish nutrition. Roma Italia: FAO. 1980. 24.
- González J, Auró de Ocampo A, Anislao V. Evaluation of the common carp (*Cyprinus carpio*, var. *communis*) growth fed when ensiled pig feces. *Veterinaria México* 2002; 33: 109-118.
- Hepher B, Pruginin Y. *Comercial fish farming with special reference to fish culture in Israel*. John Wiley and Sons, New York. 1981. 261.
- Molina AI, Granados G, Quiroz H. Productividad primaria y crecimiento de carpas chinas en estanques rústicos. *Acta Universitaria* 2003; 13: 66-74.
- Moustaka M, Nikolaidis G. Phytoplankton and physical-chemical features of Tavropos reservoir Greece. *Hydrobiologia* 1992; 228: 141-149.
- Navarrete NA, Elias G, Contreras G, Rojas M. Policultivo de carpas y tilapia en bordos rurales del Estado de México. *Hidrobiologica* 2002; 10: 35-40.
- Nikolova L, Hadjinikolova L, Dochin K, Terziyski D, Atanasova R, Stoeva A, *et al.* Carp fish rearing in autochthonous polyculture of one and the same age (*Cyprinus Carpio* L., *Aristichthys Nobilis* Rich. and *Ctenopharyngodon Idella* Val.). *Bulgarian Journal Agriculture Science* 2008a; 14: 133-138.

- Nikolova L, Hadjinikolova L, Dochin K, Terziyski D, Atanasova R, Stoeva A, *et al.* Carp fish rearing in autochthonous mixed polyculture (*Cyprinus Carpio*, L., *Aristichthys nobilis* and *Ctenopharyngodon Idella* Val.). *Bulgarian Journal Agriculture Science* 2008b; 14: 139-144.
- O'Brien WJ, De Noyelles F. Relationship between nutrient concentration phytoplankton density and zooplankton density in nutrient enriched experimental ponds. *Hydrobiologia* 1974; 44: 105-125.
- Olah J. Carp production in manure ponds. *In:* Billard, R. and J. Marcel (eds): *Aquaculture of Cyprinids*: Paris. INRA 1986; 295-303.
- Padmavathi P, Prasad KD. Studies on the influence of plankton on fish production of carp culture ponds of Krishna district, Andhra Pradesh, India. *Ecology Environment and Conservation* 2009; 15: 473-479.
- Ponce JT, Arredondo JL, De La Lanza G. Effects of polyculture and fertilization on water quality in carp ponds. 1. Physico-chemical factors. *Verhandlungen des Internationalen Verein Limnologie* 1994; 25: 1315-1317.
- Schroeder GL. Night time material balance for oxygen in fish ponds receiving organic wastes. *Bamidgeh* 1975; 27: 65-74.
- Tang YA. Evaluation of balance between fishes and available fish food in multispecies fish culture ponds in Taiwan. *Transactions of the American Fisheries Society* 1970; 99: 708-718.
- Vadas RL. The springtime phytoplankton of two calcareous ponds in Ohio. *Journal Freshwater Ecology* 1992; 7: 407-418.
- Vromant N, Nam CQ, Ollevier F. Growth performance and use of natural food by *Oreochromis niloticus* (L.) in polyculture systems with *Barbodes gonionotus* (Bleeker) and *Cyprinus carpio* (L.) in intensively cultivated rice fields. *Aquaculture Research* 2002; 33: 969-978.
- Wilkins D, Piedrahita R. The relation between phytoplankton and dissolved oxygen in fish ponds. *Aquaculture* 1988; 68: 249-265.