Asian Fisheries Science 11(1998):287-294
Asian Fisheries Society, Manila, Philippines

https://doi.org/10.33997/j.afs.1998.11.3-4.012

Feeding of Napier (*Pennisetum purpureum*) to Grass Carp in Polyculture: A Sustainable Fish Culture Practice for Small Farmers

M.K. SHRESTHA[a,b] and C.N.R. YADAV[a]

[a] *Institute of Agriculture and Animal Science*
Fisheries and Aquaculture Department,
Rampur, Chitwan, Nepal

[b] *Agricultural and Aquatic Systems Program*
Asian Institute of Technology
P.O. Box 4, Klong Luang
Pathumthani 12120, Thailand

Abstract

An experiment was conducted in outdoor cement ponds for three months to evaluate the growth and production of grass carp (*Ctenopharyngodon idella*) and other polycultured species fed with napier grass (*Pennisetum purpureum*). Chopped fresh napier grass was fed every day at *ad libitum* to grass carp stocked in three combinations in triplicates: (1) monoculture of grass carp; (2) polyculture of grass carp, silver carp (*Hypophthalmichthys molitrix*) and bighead carp (*Aristichthys nobilis*); and (3) polyculture of grass carp, silver carp, bighead carp and common carp (*Cyprinus carpio*). Mean net fish yield (NFY) of grass carp obtained was: 1.22, 1.25±0.05 and 1.04±0.01 $g \cdot m^{-2} \cdot day^{-1}$ with total NFY of 1.22, 1.62±0.04 and 1.44±0.01 $g \cdot m^{-2} \cdot day^{-1}$ in treatments 1, 2 and 3, respectively. Mean food con-version ratio (FCR) of fresh napier grass to grass carp production was 17.3, 17.9±0.6 and 21.9±0.4, whereas, to total fish production, this was 17.3, 13.5±0.3 and 15.0±0.3 in treat-ments 1, 2 and 3, respectively. Results clearly indicated that waste of grass carp cultivation fed on grass can support the production of other fish species and that, as shown by NFY and FCR, grass carp and common carp compete on grasses. Water quality was less a prob-lem in polyculture than that in monoculture despite the higher stocking density in polyculture. Mass mortality of grass carps occurred in two replications of monoculture treatment due to the low level of dissolved oxygen in the ninth week of the experiment.

Introduction

The high cost of fish feeding is a major constraint to small-scale and resource-poor farmers in developing countries. While commercial fish farmers can apply formulated or conventional feeds without regard to cost, fish in ponds belonging to small farmers are often left unfed. Exploration of easily cultivable non-conventional plant feedstuff is a prime consideration in solving problems of small-scale fish farmers (De Silva 1993). Varieties of vegetation are used as feed/fertilizer in ponds with commonly cultured herbivorous fish species (Sen *et al.* 1978; Tripathi and Mishra 1986; Santos 1993; Verma 1994; Chikafumbwa 1996). However, selection criteria of the vegetation should also consider its year-round availability, minimum management practice and high productivity.

Napier (*Pennisetum purpureum*), a perennial tropical fodder grass (Humprey 1978), can be planted in pond dikes and slopes as a source of feed and fertilizer (Huazhu and Baotong 1989). Grass carp (*Ctenopharyngodon idella*) is a well-known herbivorous fish which feeds on aquatic weeds, both soft and hard, as well as leaves of plants and grasses supplied in water. Between 25 and 30°C, the fish can eat a quantity of plants equal to 25-50% of its body weight within a day (Woynarovich 1975). The digestive process of grass carp is rapid at high temperatures and the feces, along with scarcely digested food, is emptied in the water, serving as efficient "green fertilizer" (Woynarovich 1975). Due to very fast and incomplete digestion, the major portion of the plants consumed by this herbivorous fish returns to the pond water as organic manure, stimulating bacterial and plankton production for raising other planktivorous fish in polyculture ponds. It is estimated that excreta from 1 kg of this fish is sufficient to fertilize pond waters to produce 0.2-0.5 kg of plankton feeder fish (Huazhu and Baotong 1989). The objective of this study was to determine the efficiency of napier grass as food source for grass carp in monospecies and polyculture systems.

Materials and Methods

An experiment was conducted in outdoor concrete tanks (5 m x 4.8 m x 1.5 m) at the Institute of Agriculture and Animal Science (IAAS), Rampur, Chitwan, Nepal. The tanks were filled with tap water to about 1 m and new water was added weekly to compensate for evaporative losses.

The experimental design included three treatments with three replications each: (1) monoculture of grass carp (1 fish m^{-2}); (2) polyculture of grass carp (1 fish m^{-2}) with silver carp, *Hypophthalmichthys molitrix* (0.25 fish$\cdot m^{-2}$) and bighead carp, *Aristichthys nobilis* (0.25 fish$\cdot m^{-2}$); and (3) polyculture of grass carp (1 fish$\cdot m^{-2}$) with silver carp, *Hypophthalmichthys molitrix* (0.25 fish$\cdot m^{-2}$), bighead carp, *Aristichthys nobilis* (0.25 fish$\cdot m^{-2}$) and common carp, *Cyprinus carpio* (0.25 fish$\cdot m^{-2}$) (Table 1). Grass carp (9-11 g size) was stocked on 30 July 1995. Silver carp (19-21 g), bighead carp (13-16 g) and common carp (5-7 g) were stocked one week later. The total growing period was 97 and 90 days for grass carp and the other species, respectively. Chopped fresh napier (cultivated in the campus farm) leaf was the sole pond input and was provided every day *ad libitum*. The daily grass consumption was calculated by subtracting the leftover feed from the initial weight of grass provided in a span of 24 hours.

Analytical Methods

Proximate analysis of fresh napier grass

Two batches of fresh napier grass, with three replications in each batch, were analyzed for moisture, crude protein (CP), ether extract (EE), crude fiber (CF), nitrogen free extract (NFE) and ash following the procedure of Cockerell *et al.* (1975).

Table 1. Stocking combination and mean stocking, harvest, net fish yield (NFY) and food conversion ratio (FCR) of carps in monoculture and polyculture systems fed with fresh chopped napier grass (Mean±1 SE).

Treatment	Species	Stocking size (g)	Survival(%)	Harvest size (g)	Mean NFY	Mean FCR
Monoculture*	Grass carp	9.8±0.3	100.0	128.9	1.22 ^{a}	17.3 ^{a}
Total					1.22 ^{c}	17.3 ^{c}
Polyculture-1	Grass carp	10.7±0.1	98.6	133.6±3.5	1.25±0.05 ^{a}	17.9±0.6 ^{a}
	Silver carp	19.8±0.6	100.0	73.8±1.6	0.15±0.00 ^{a}	
	Bighead carp	16.3±0.6	100.0	96.8±2.4	0.23±0.01 ^{a}	
Total					1.62±0.04 ^{a}	13.5±0.3 ^{a}
Polyculture-2	Grass carp	9.2±0.2	93.1	118.3±2.6	1.04±0.01 ^{b}	21.9±0.4 ^{b}
	Silver carp	19.8±0.5	100.0	55.6±2.4	0.10±0.01 ^{b}	
	Bighead carp	13.1±2.2	100.0	71.0±2.8	0.16±0.01 ^{b}	
	Common carp	6.1±0.4	94.4	59.8±3.4	0.14±0.01	
Total					1.44±0.01 ^{b}	15.0±0.3 ^{b}

NFY and FCR means sharing same superscript within same species and between treatment total are not significantly different at $P < 0.05$.
* In monoculture treatment almost all the fish died in 2 replications and the data were excluded in the analysis.

Water quality analysis

Water quality in tanks was monitored weekly (Table 2). Measurements included *in situ* water temperature at 0600 h and 1500 h and dissolved oxygen (DO) at 0600 h with a DO meter (YSI meter model 50 B) and *in situ* pH at 0600 h and 1500 h with a pH meter (WTW pH 91).

Biological productivity

Biweekly gross productivity (GPP) and net primary productivity (NPP) were estimated from diel changes in DO at pond depths of 10, 30, 50, 70 and 90 cm at 0600 h, at 1800 h, and again at 0600 h of the following day (Hall and Moll 1975).

Fish production

Net fish yield (NFY) was calculated as $g \cdot m^{-2} \cdot day^{-1}$ by dividing the difference between total initial (stocking) and final (harvest) fish biomass per tank by the surface area of the tank (24 m^2) and by the experimental period (97 and 90 days for grass carp and the other species, respectively).

Food conversion ratio (FCR)

Considering the quantity of napier grass fed and NFY, FCR of grass carp and other stocked species was calculated by dividing the amount of total grass consumed by the NFY.

Data analysis

The data were analyzed using one-way analyses of varience. Least significant difference (LSD) was used where necessary using Statgraphic 5 statistical software package. Data from two replications of monoculture treatment were excluded from analysis due to mass mortality of fish. Means are given with ±1 standard error (SE) and statistical significance is given at $P<0.05$.

Results

Nutritive Value of Napier Grass

Proximate analysis of fresh napier grass showed that it contained 81.2±0.97% of moisture and 9.9±1.21, 5.0±0.22, 30.2±1.91 and 39.1±3.00% of CP, EE, CF and NFE, respectively, on dry matter basis.

Fish Growth and Net Fish Yield

Mean weight of stocked and harvested fish and their survival in monoculture and polyculture treatments are shown in Table 1. Mass mortality of grass

Table 2. Weekly water quality measurements during the experimental period.

Variable	Monoculture	Polyculture-1	Polyculture-2
Temperature range (°C)	23.5-34.1	23.3-34.5	23.3-34.3
pH range	8.0-9.7	8.0-9.7	8.0-9.5
DO range ($mg \cdot L^{-1}$) at 0600h	0.9-7.6	0.8-10.6	0.5-8.4
NPP range* ($mg\ O_2 \cdot L^{-1} \cdot 12h^{-1}$)	0.7-5.8	3.5-6.6	2.7-6.3
GPP range* ($mg\ O_2 \cdot L^{-1} \cdot 12h^{-1}$)	1.7-11.6	6.7-12.8	5.9-12.3

*Biweekly measurement using diel change in DO.

carp occurred (22 out of 24) in two replications of monoculture during the end of the ninth week of the experiment.

The mean net fish yield (NFY) calculated in $g \cdot m^{-2} \cdot day^{-1}$ in the different species and treatments are shown in Table 1. The NFY of grass carp was not significantly different between monoculture and polyculture; however, it decreased significantly in polyculture including common carp. The total NFY was significantly higher in polyculture than that in monoculture, performing best in polyculture with three species (grass + silver + bighead carps) (Table 1). Extrapolation of total NFY in three treatments were 12.2, 16.2±0.4 and 14.4±0.1 $kg \cdot ha^{-1} \cdot day^{-1}$, or 4.5, 5.9±0.2 and 5.2±0.0 $t \cdot ha^{-1} \cdot year^{-1}$ in monoculture of grass carp, polyculture of grass carp with silver and bighead carps, and polyculture of grass carp with silver, bighead and common carps, respectively.

Food Conversion Ratio

Conversion of napier grass to grass carp in Treatment 1 (monoculture) and Treatment 2 (polyculture with silver + bighead carps) were significantly lower compared to Treatment 3 (polyculture with silver + bighead + common carps) (Table 1). However, FCR for total fish production in both polyculture treatments was significantly lower than that in monoculture. This was particularly true in three-species polyculture (grass + silver + bighead carps).

Water quality

The weekly and biweekly measurements of water temperature, pH, DO, NPP and GPP during the experimental period are presented in Table 2. DO concentrations and NPP and GPP in grass carp monoculture ponds were consistently low from Week 9 and 11 and in Week 11, respectively (Figs. 1 and 2). The constantly low DO and low NPP and GPP coincided with the mass mortality of grass carps in two replications of the monoculture treatment.

Discussion

Pond fertilization and supplemental feeding are commonly practiced in the semi-intensive fish culture of herbivorous species. However, fertilizers and/or feeds are often either too expensive or unavailable for resource-poor farmers, making fish culture a question of economic viability. Although chopped napier

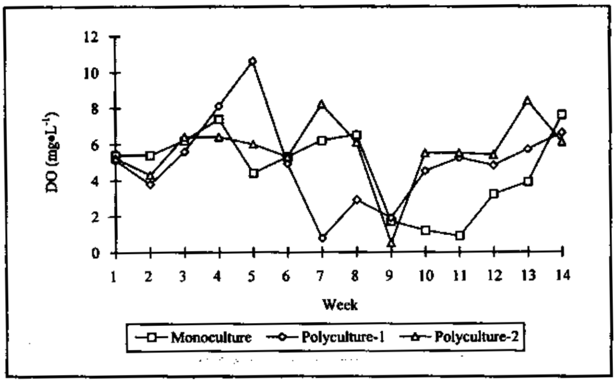

Figure 1. Weekly dissolved oxygen (DO mg·L^{-1}) at 600 h in monoculture and polyculture system.

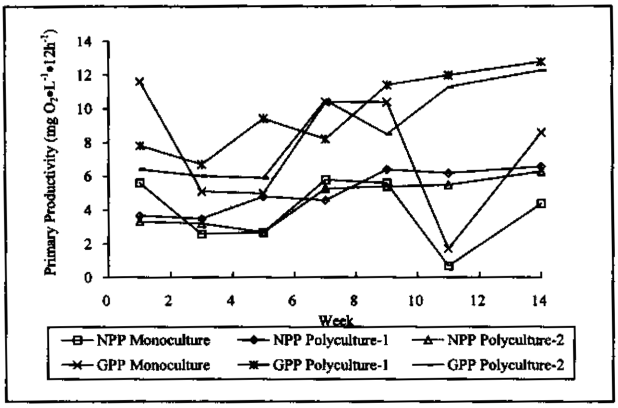

Figure 2. Biweekly net (NPP) and gross primary productivity (GPP) (mg O_2·L^{-1}·12 h^{-1}) in monoculture and polyculture system.

grass contained only 9.9% of CP compared to 28% in *Ipomaea aquatica*, 19.5% in *Manihot esculenta*, 20.9% in *Lemna minor*, 19.4% in *Ipomaea batatus* and 23% in *Amaranthus sp.* (Tacon 1987; Santos 1993), its perennial nature, year-round availability and hardiness (with the least management) are the major advantages for small, resource-poor farmers. Production of grass carp in monoculture and polyculture ranged from 10.4±0.1 to 12.5±0.5 kg•ha^{-1}•day^{-1}, but an extra yield of 3.8 and 4.0 kg•ha^{-1}•day^{-1} was obtained from polyculture of three and four species treatment, respectively (Table 1). Similar total fish yields of 12.3-15.1 kg•ha^{-1}•day^{-1} has been reported in grass carp dominated six species polyculture system fed with aquatic weeds (Tripathi and Mishra 1986). Venkatesh and Shetty (1978) reported that a grass carp yield of 8.7 kg•ha^{-1}•day^{-1} with a FCR of 27 was obtained when fish were fed with hybrid napier (*P. purpureum x P. typhoideum*) and stocked at 0.5 fish•m^{-2}. The fish yield was 3-4 times higher than that from fed with *Hydrilla* and *Ceratophyllum*, clearly indicating the suitability of napier as a feed for grass carp. Total fish production increases when feeding grass carp with napier in combination with filter feeder (silver and bighead carp) and bottom feeder species (common carp). Moreover, the high percentage of CF content (30.2%) in napier grass appears to enhance evacuation of undigested and partially digested food that may served as detritus and nutrients for plankton production. Increase in CF content in feed reduces energy density of food and enhances gastric evacuation rate (Jobling 1980).

Mass mortality of grass carp in monoculture in the present experiment suggests that species diversity (plankton feeders) is necessary to maintain balanced pond ecosystems, e.g., utilization of nutrients and cropping of plankton that otherwise create oxygen depletion due to plankton die off and decomposition (Figs. 1 and 2). Results showed that, despite higher stocking densities in polyculture systems (1.5 fish$\cdot$m^{-2} and 1.75 fish$\cdot$m^{-2}) compared to monoculture (1 fish$\cdot$m^{-2}), water quality was less a problem in the former systems. This suggests that monoculture of grass carp fed with a large amount of grass is risky in stagnant ponds. Polyculture with plankton feeder fish can maintain desirable water quality, whereas monoculture requires better management of water quality or reduces stocking density, making it economically impracticable for small farmers where water is limited.

The lower NFY and higher FCR (Table 1) in polyculture of grass carp and common carp compared to those in monoculture suggest that the common carp feeds on napier grass and that there is a feeding competition between grass carp and common carp. But, due to lack of other foods, the common carp might have consumed napier grass since it has no other choice. Even then, common carp provided extra yield but at the expense of grass and plankton feeder carps. The results of this experiment show that grass carp grows well with napier feed and that incorporation of plankton feeder fish (silver and bighead carps) significantly increases fish yield to about 16 kg$\cdot$ha$^{-1}\cdot$day^{-1}, yet maintaining acceptable water quality in stagnant ponds. The extrapolated yield of about 6 t$\cdot$ha$^{-1}\cdot$year^{-1} without water exchange or aeration is considered high yield with feeding grass as a sole input in a semi-intensive system.

Farming of grass carp in polyculture with plankton feeder fish and silver and bighead carp, with napier grass as a sole input, could be a sustainable fish culture practice for resource-poor small farmers in Asia and Africa.

Acknowledgments

This study was funded by FFP\TU\IDRC through the Directorate of Research, IAAS, Rampur, Chitwan, Nepal. The authors would like to acknowledge Prof. C. Kwei Lin, Asian Institute of Technology, Thailand, for his critical review of the manuscript and useful suggestions.

References

Chikafumbwa, F.J.K. 1996. The use of napier grass (*Pennisetum purpureum*) and maize (*Zea mays*) bran as low-cost tilapia aquaculture inputs. Aquaculture 146:101-107.

Cockerell, I., D. Halliday and D.J. Morgan. 1975. Quality control in the animal feedstuff manufacturing industry. Tropical Products Institute, Publication No. G 97, London.

De Silva, S.S. 1993. Supplementary feeding in semi-intensive aquaculture system. In: Farm-made Aquafeeds (ed. M.W. New, A.G.J. Tacon and I. Csavas), pp. 24-60. Proceedings of the FAO/AADCP Regional Expert Consultation on Farm-Made Aquafeeds, 14-18 December 1992, Bangkok, Thailand. FAO-RAPA/AADCP, Bangkok.

Hall, C.A.S. and R. Moll. 1975. Methods of assessing aquatic primary productivity. In: Primary Productivity of the Biosphere (ed. H. Lieth and R.H. Whittaker), Springer-Verlag, New York.

Huazhu, Y. and H. Baotong. 1989. Introduction of Chinese integrated fish farming and some other models. In: Integrated fish farming in China. NACA Technical Manual 7, Network of Aquaculture Centres in Asia and Pacific, Bangkok.

Humprey, L.R. 1978. Tropical pastures and fodder crops. Longman Group Limited, Longman House, England.

Jobling, M. 1980. Gastric evacuation in plaice, *Pleuronectes platessa* L.: effects of dietary energy level and food composition. Journal of Fish Biology 17:187-196.

Santos, E.V. 1993. Utilization of selected terrestrial vegetation and aquatic macrophytes by the herbivorous fish, silver barb (*Puntius gonionotus*). AIT Diss. No. AE-93-2.

Sen, P.R., N.G.S. Rao, R.D. Chakrabarty, S.L. Kar and S. Jena. 1978. Effects of additions of fertilizers and vegetation on growth of major indian carps in ponds containing grass carp. The Progressive Fish-Culturist 40:69-70.

Tacon, A.G.H. 1987. The nutrition and feeding of farmed fish and shrimp - A training manual. 2. Nutrient sources and composition. Food and Agriculture Organization of the United Nations, Brasilia. 129 pp.

Tripathi, S.D. and D.N. Mishra. 1986. Synergistic approach in carp polyculture with grass carp as a major component. Aquaculture 54:157-160.

Venkatesh, B. and H.P.C. Shetty. 1978. Studies on the growth rate of the grass carp *Ctenopharyngodon idella* (Valenciennes) fed on two aquatic weeds and a terrestrial grass. Aquaculture 13:45-53.

Verma, S.K. 1994. Water hyacinth, *Eichhornia crassipes* (Mart.) Solms., as direct feed for grass carp (*Ctenopharyngodon idella*, Cuv. & Val.). Journal of Freshwater Biology 6:323-326.

Woynarovich, E. 1975. Elementary guide to fish culture in Nepal. Food and Agriculture Organization of the United Nations, Rome. 131 pp.

Manuscript received 11 April 1997; Accepted 3 August 1998.