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Evaluation of three organic fertilizers for paddlefish, *Polyodon spathula*, production in nursery ponds

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ABSTRACT

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Organic fertilization of paddlefish (*Polyodon spathula*) nursery ponds with rice bran (RB), distiller's dry grain (DG) or cottonseed meal (CSM) was evaluated in nine 0.02-ha ponds over a 40-d period. Net yields (kg/ha) and growth rate of fish in ponds fertilized with RB were significantly higher ($P \leq 0.05$) than with CSM, but not significantly different ($P > 0.05$) in ponds fertilized with DG. There was no significant difference ($P > 0.05$) in fish survival (RB 77%, DG 79%, and CSM 65%) for ponds receiving any of the three fertilizers. Secchi disk visibility and dissolved oxygen were significantly lower ($P \leq 0.05$) in ponds fertilized with RB than in ponds fertilized with CSM and DG. Ammonia and nitrite levels differed only during week 3 and were significantly higher ($P \leq 0.05$) in ponds fertilized with CSM and DG than in ponds fertilized with RB. Large cladocerans (*Daphnia, Simocephalas, Scaphaleberis*) were the dominant food items found in stomachs of fish in all treatments. RB proved to be superior to CS and DG as an organic fertilizer for paddlefish nursery ponds when evaluated in terms of fingerling growth, water quality, and zooplankton production.

INTRODUCTION

Organic fertilizers are agricultural or industrial by-products applied to ponds to promote development of natural food organisms eaten by many cultured larval and fingerling fish (Geiger et al., 1985). Cultured fish species traditionally grown in fertilized nursery ponds include striped bass (*Morone saxatilis*) (Bonn et al., 1976; Geiger et al., 1985), largemouth bass (*Micropterus salmoides*) (Rogers, 1967) and walleye (*Stizostedion vitreum*) (Nickum, 1986). In recent years, paddlefish (*Polyodon spathula*) has been considered a possible culture species (Michaletz et al., 1982; Burke and Bayne, 1986; Semmens and Shelton, 1986).

Young paddlefish (<120 mm total length (TL)) are particulate feeders

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and consume large cladocerans, especially *Daphnia*. Older fish (≥120 mm TL) are filter feeders and feed on all zooplankton in the pond (Michaletz et al., 1982). Various types, quantities, and combinations of organic fertilizers in paddlefish nursery ponds have been used to stimulate zooplankton growth (primarily cladocerans) while maintaining suitable water quality for growth and development of the fish (Graham et al., 1986). Michaletz et al. (1982) reported fingerling size of 120 mm TL after 80 d in ponds fertilized with a combination of brewer's yeast, chicken manure, alfalfa meal, and dehydrated cow manure and stocked at 55 000 larvae/ha. Semmens (1982) found that ponds fertilized with alfalfa pellets and meat/bone meal, inoculated with *Daphnia* spp., and stocked at 53 000 larvae/ha would produce fingerlings about 100 mm in TL after 40 d.

Survival of paddlefish in nursery ponds has been quite variable. Unkenholz (1977) reported an average survival of 9.7%; Michaletz et al. (1982) reported an average survival of 16.0% and Semmens (1982) reported average survivals ranging from 9% to 58%. Geiger et al. (1985) has shown that fingerling striped bass survival improved with an organic fertilizer used in conjunction with liquid inorganic fertilizer and a zooplankton inoculation.

The objective of this study was to evaluate and identify a commercially available organic fertilizer for increasing survival and growth of paddlefish fingerlings (> 120 mm TL) in primary nursery ponds.

MATERIALS AND METHODS

Pond management

Nine 0.02-ha earthen ponds located at Kentucky State University Aquaculture Research Center in Frankfort, KY, were used. Three ponds were randomly assigned to each of the treatments. Ponds received a pre-flooding treatment with Aquazine® as described by Snow (1977) to control filamentous algae. On 20 April 1988, ponds were filled to 1.1-m depth with water taken from a surface-water reservoir and filtered through 385-μm saran cloth socks.

Three types of organic fertilizers were evaluated: cottonseed meal (CSM), distiller's dry grain (DG), and rice bran (RB). The quantities and application schedule of CSM as described by Geiger et al. (1985) were used as the control treatment (Table 1). Quantities and application schedules for the DG and RB ponds were based on the nitrogen contents of the control (CSM) treatment (Geiger et al., 1985; Green et al., 1989). Organic fertilizers were analysed according to Horwitz (1980) and are presented in Table 2. Ponds received liquid ammonium polyphosphate (13–34–0) at application rates found in Table 1.

Zooplankton, predominately *Daphnia*, were inoculated at a rate of about 125 000 crustaceans per pond on 20, 21 and 22 April. Air-lift pumps (5-cm polyvinyl chloride) were installed and continuously run in each pond to pro-

TABLE 1

Organic and inorganic fertilization rates for 0.02-ha ponds stocked with 61 775 larval paddlefish ha

Week	No. of applications	Organic fertilizers[1]			Inorganic fertilizer[2] (l/ha)
		Cottonseed meal	Distiller's dried grain	Rice bran	
		← (kg/ha) →			
Initial[3]	6	397	624	1114	37.0
1	3	89	140	250	4.6
2	2	45	70	126	9.3
3[4]	0	0	0	0	0
4	2	45	70	126	9.3
5	2	45	70	126	9.3

[a]Organic fertilizers were divided into indicated number of applications.
[2]All treatments received the same amount of inorganic fertilizer (13–34–0).
[3]Initial represents pre-stocking fertilization.
[4]No fertilizers were applied in any treatment due to increasing ammonia and nitrite levels in ponds fertilized with cottonseed meal or distiller's dried grain.

TABLE 2

Analysis of organic fertilizers applied to 0.02-ha ponds stocked with 61 775 larval paddlefish/ha[1]

Composition	Cottonseed meal (%)	Distiller's dried grain (%)	Rice bran (%)
Crude protein	39.3	25.0	14.0
Crude fat	3.1	9.4	18.9
Crude fiber	12.4	23.0	5.9
Moisture	10.0	9.0	9.5
Free gossypol	0.1	–	–
Phosphorus	1.2	1.0	1.5
Potassium	1.6	0.7	1.5
Magnesium	0.6	0.8	0.8
Calcium	0.1	0.7	1.1

[1]Official methods of organic fertilizer analysis were followed as described by Horwitz (1980).

vide thorough mixing of nutrients and zooplankton during the study (Parker, 1979).

Paddlefish larvae, produced from broodfish collected in Kentucky, were held in rearing boxes for 8 d until mouth parts were well developed, peristalsis had begun and they were actively seeking food (Graham et al., 1986). Larvae had an average TL of 16.9±0.2 mm (X±s.d.) and weight of 19.6±2.0 mg. Larvae were stocked into ponds before dawn on 4 May at a rate of 61 775/ha. Fish were harvested after 40 d.

Water quality analysis and management

Dissolved oxygen (DO) and water temperature (polargraphic dissolved oxygen meter and thermistor, Yellow Springs, OH) and pH (Omega PHH-43 meter, Stamford, CT) were measured at 07.00 and 15.00 h daily in each pond. Secchi disk visibility (cm) was measured daily at 07.00 h. Water samples were collected weekly from each pond and analysed for alkalinity (as $CaCO_3$), ammonia-nitrogen (NH_3-N), nitrite-nitrogen (NO_2-N), and total filterable orthophosphates (PO_4-P) (Hach DREL/5, Loveland, CO). Chlorophyll-*a* was extracted from water samples with acetone and measured spectrophotometrically (APHA et al., 1980). Emergency aeration was provided by 0.33-hp surface agitators whenever the dissolved oxygen concentration was predicted by graph (Boyd, 1979) to fall below 50% of saturation (Andrews et al., 1973). Ponds were treated with 17 kg/ha Aquazine® on weeks 3 and 5 to control filamentous algae.

Zooplankton sampling

Zooplankton samples were collected with a flexible-impeller pump as described by Geiger (1983). Water samples (10 l) were collected from the pond standpipe area twice weekly, passed through a 80-μm Wisconsin-style plankton net, and the concentrate preserved in cold 5% buffered formalin with sucrose (Haney and Hall, 1973). Zooplankton were counted in a Sedgewick–Rafter cell with a compound microscope and expressed as number of organisms per liter. Zooplankton counts per pond were combined providing two complete zooplankton sampling replicates per pond per week. Cladocerans were identified to species and copepods to suborder using current taxonomic references.

Larval fish sampling and stomach analysis

Ten paddlefish were collected from each pond weekly and preserved in 10% buffered formalin. Five of the 10 preserved fish were used for stomach analysis. The stomach was carefully opened and rinsed into a Sedgewick–Rafter counting chamber. Stomach contents samples were counted and identified to the same taxon levels as described in the previous section. At harvest, an additional 40 fish were sampled for final individual TL and weight and preserved.

Prey selection

A linear food selection index (Strauss, 1979) was used to compare the prey consumed by predators with the availability of the prey in the environment

$$L = r_i - p_i$$

where r_i is the proportion of prey taxon eaten and p_i is the proportion of the same prey taxon in the environment. The index has values ranging from -1

to +1. Negative values indicate avoidance or inaccessibility and positive values indicate preference of prey items (Michaletz et al., 1982).

Data analysis

Fish and zooplankton date were compared among treatments by analysis of variance using Microstat (Ecosoft, Inc., Indianapolis, IN). Mean separation was by Fisher's Least Significant Difference test (Snedecor and Cochran, 1967). The level of significance for all tests was $P \leq 0.05$.

RESULTS

Fish yield and survival

Net yield in ponds fertilized with RB was significantly greater ($P \leq 0.05$) and growth rate of fish was significantly higher ($P \leq 0.05$) than in ponds fertilized with CSM, but not significantly different ($P > 0.05$) from ponds fertilized with DG (Table 3). A definite relationship between treatments was established by week 4 and was maintained through the remainder of the study (Fig. 1). RB was the only treatment that produced fish, able to efficiently filter feed, with a mean TL greater than 120 mm. Mean survival rates among treatments were not significantly different ($P > 0.05$).

Water quality

Overall mean secchi disk visibility was significantly lower ($P \leq 0.05$) in ponds fertilized with RB than in ponds fertilized with CSM or DG. However, phytoplankton abundance, as measured by chlorophyll-*a* concentrations, was similar ($P > 0.05$) in all treatments (Fig. 2). Ponds fertilized with RB were observed to retain a brown coloration or stain throughout most of the culture period. Ponds fertilized with CSM or DG remained mostly clear. Because of the clarity of the water, filamentous algae became a problem in ponds fertilized with CSM or DG. Ranges of alkalinity (86–117 mg/l $CaCO_3$), pH (7.9–

TABLE 3

Mean harvest yield, growth rate (g/d; mm/d), and survival of paddlefish cultured in 0.02-ha ponds at 61 775 fish/ha with different types of organic fertilizers for 40 days[1]

Treatment	Production (kg/ha)	Growth rate		Survival (%)
		(g/d)	(mm/d)	
Rice bran	285±69a	0.16±0.03a	2.7±0.2a	77±15a
Cottonseed meal	149±29b	0.10±0.03b	2.2±0.3b	64±15a
Distiller's dried grain	205±19ab	0.11±0.03ab	2.4±0.2ab	79±10a

[1]Values are means ±s.e. of three replications. Means with the same letter in each column are not significantly different at $P > 0.05$.

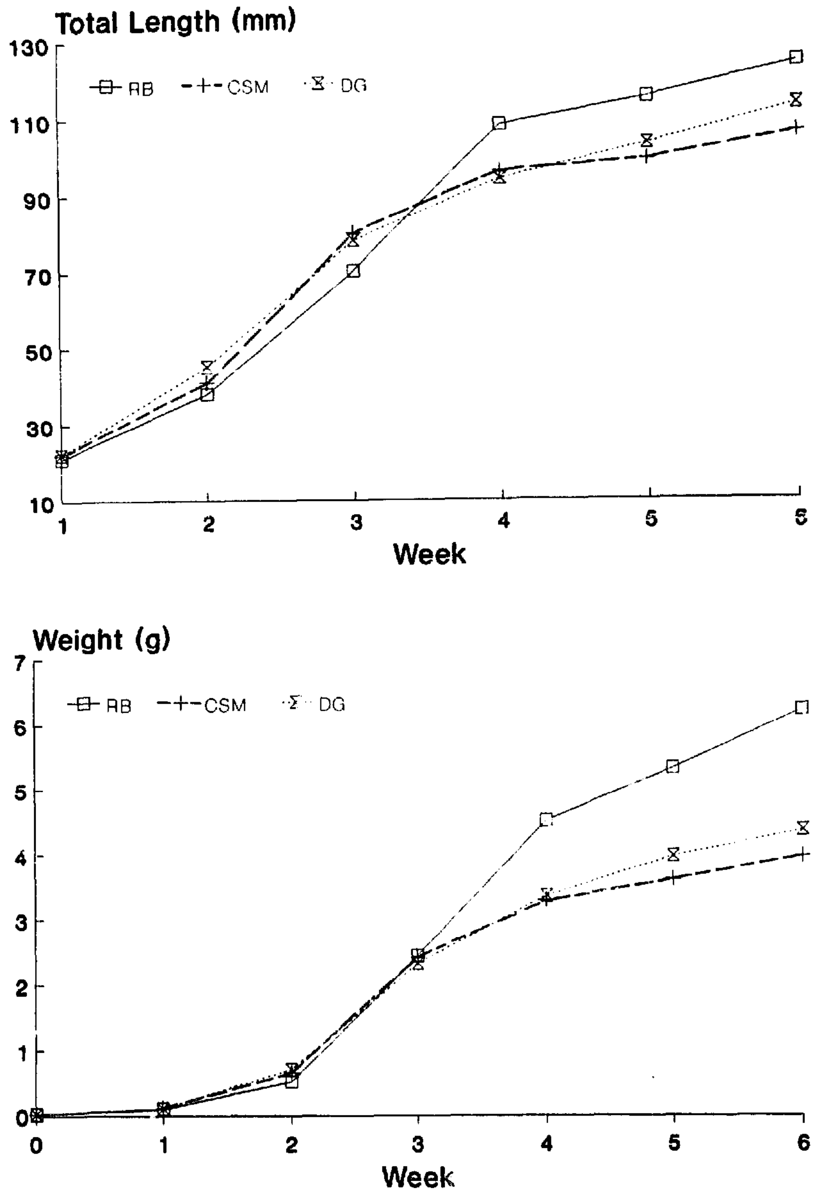

Fig. 1. Total length (mm) and weight (g) of paddlefish in ponds fertilized with rice bran (RB), cottonseed meal (CSM), or distiller's grain (DG).

9.1), and total filterable orthophosphates (1.5–6.8 mg/l) were within acceptable limits (Boyd, 1979). No significant differences ($P>0.05$) were found at any sample period.

Overall mean dissolved oxygen was significantly lower ($P\leq 0.05$) for ponds fertilized with RB (7.5 mg/l) than for ponds fertilized with CSM (9.7 mg/l) or DG (9.4 mg/l); however, DO did not fall below 50% saturation in any treatment after the fish were stocked (Fig. 3). Mean water temperatures for ponds fertilized with RB, CSM, and DG were 23.6, 24.1, and 24.3°C, respectively. Differences were not statistically significant ($P>0.05$).

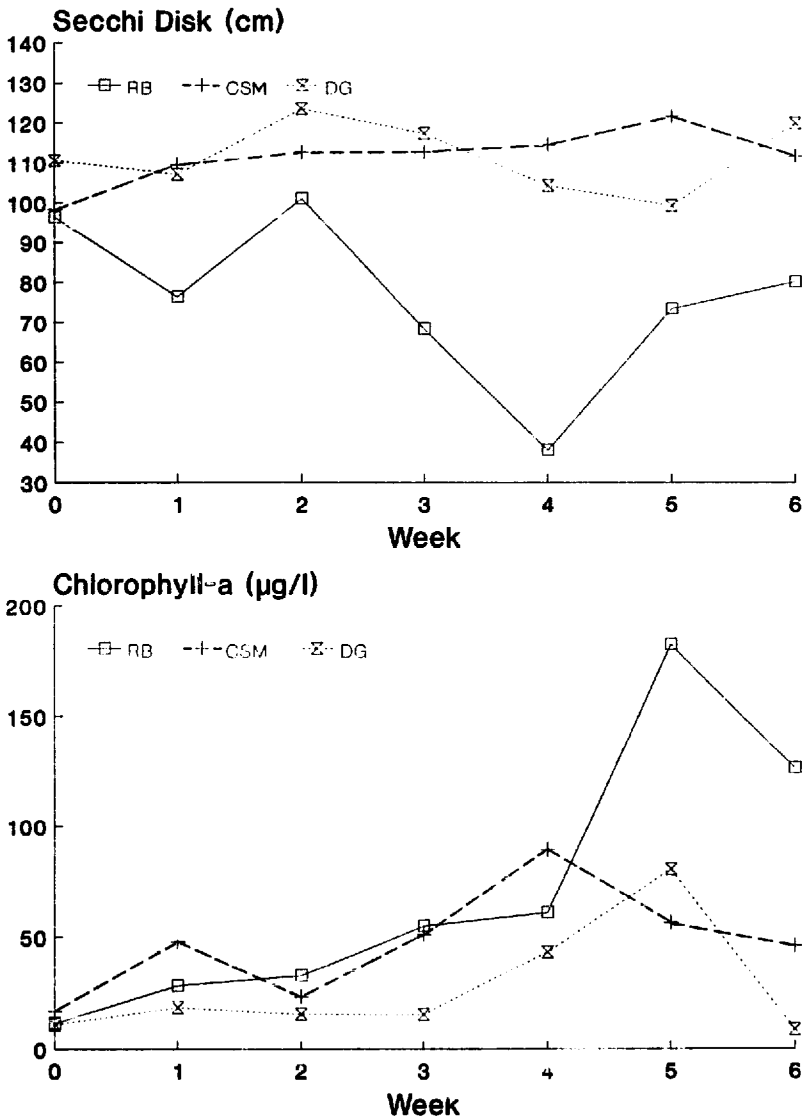

Fig. 2. Secchi disk visibility (cm) and chlorophyll-*a* concentrations (mg/l) in ponds fertilized with rice bran (RB), cottonseed meal (CSM), or distiller's grain (DG).

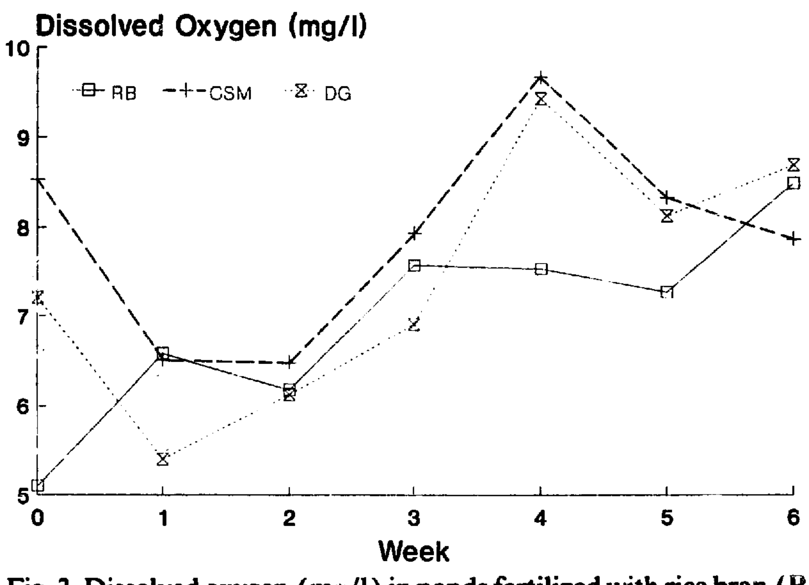

Fig. 3. Dissolved oxygen (mg/l) in ponds fertilized with rice bran (RB), cottonseed meal (CSM), or distiller's grain (DG).

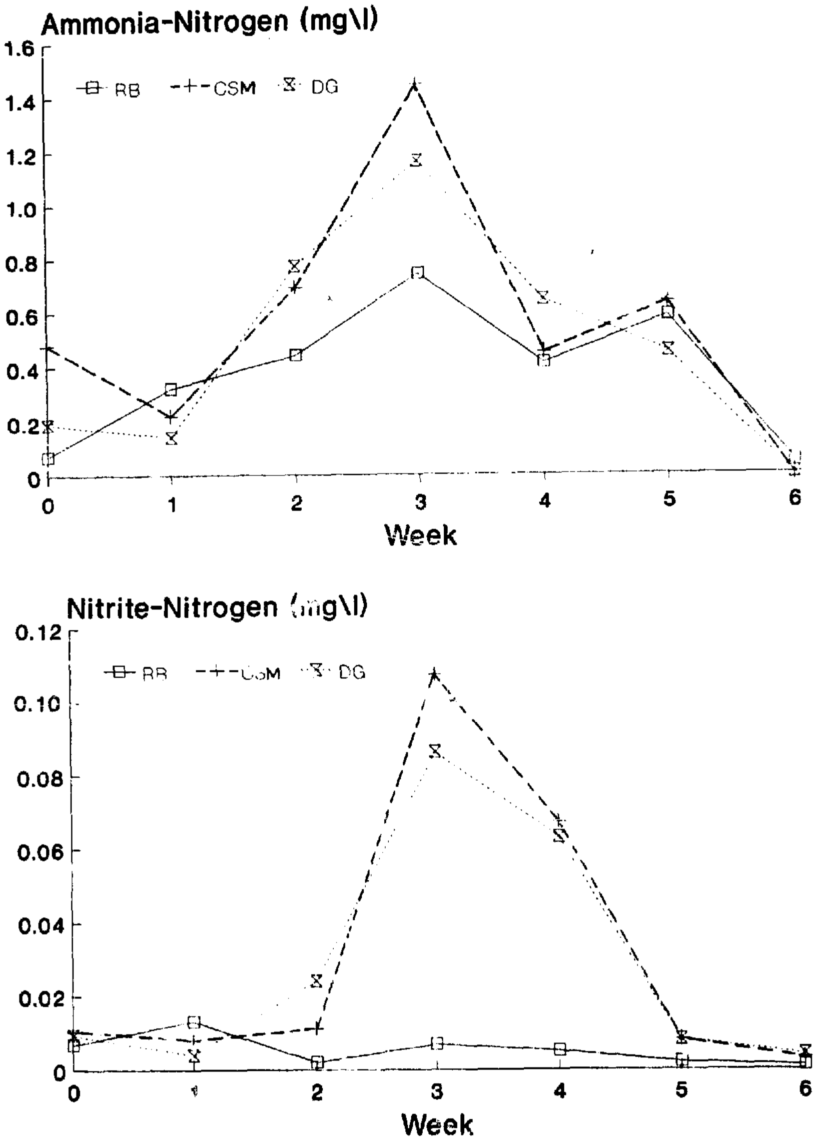

Fig. 4. Ammonia-nitrogen (mg/l) and nitrite-nitrogen (mg/l) in ponds fertilized with rice bran (RB), cottonseed meal (CSM), or distiller's grain (DG).

During week 3, ammonia and nitrite levels were significantly higher ($P \leq 0.05$) in ponds fertilized with CSM or DG than in ponds fertilized with RB (Fig. 4). Because of increasing ammonia and nitrite levels in CSM and DG treatments, all fertilization was postponed for week 3. Sodium chloride was added at 6:1 (Cl: NO_2) to prevent possible nitrite-induced anemia (Tucker et al., 1989).

Zooplankton in pond samples

Densities of large cladocerans (0.7–2.8 mm) were similar in all three treatments during the study except on week 3 (Fig. 5). During week 3, large cladocerans were not abundant ($P > 0.05$) in ponds fertilized with RB than ponds

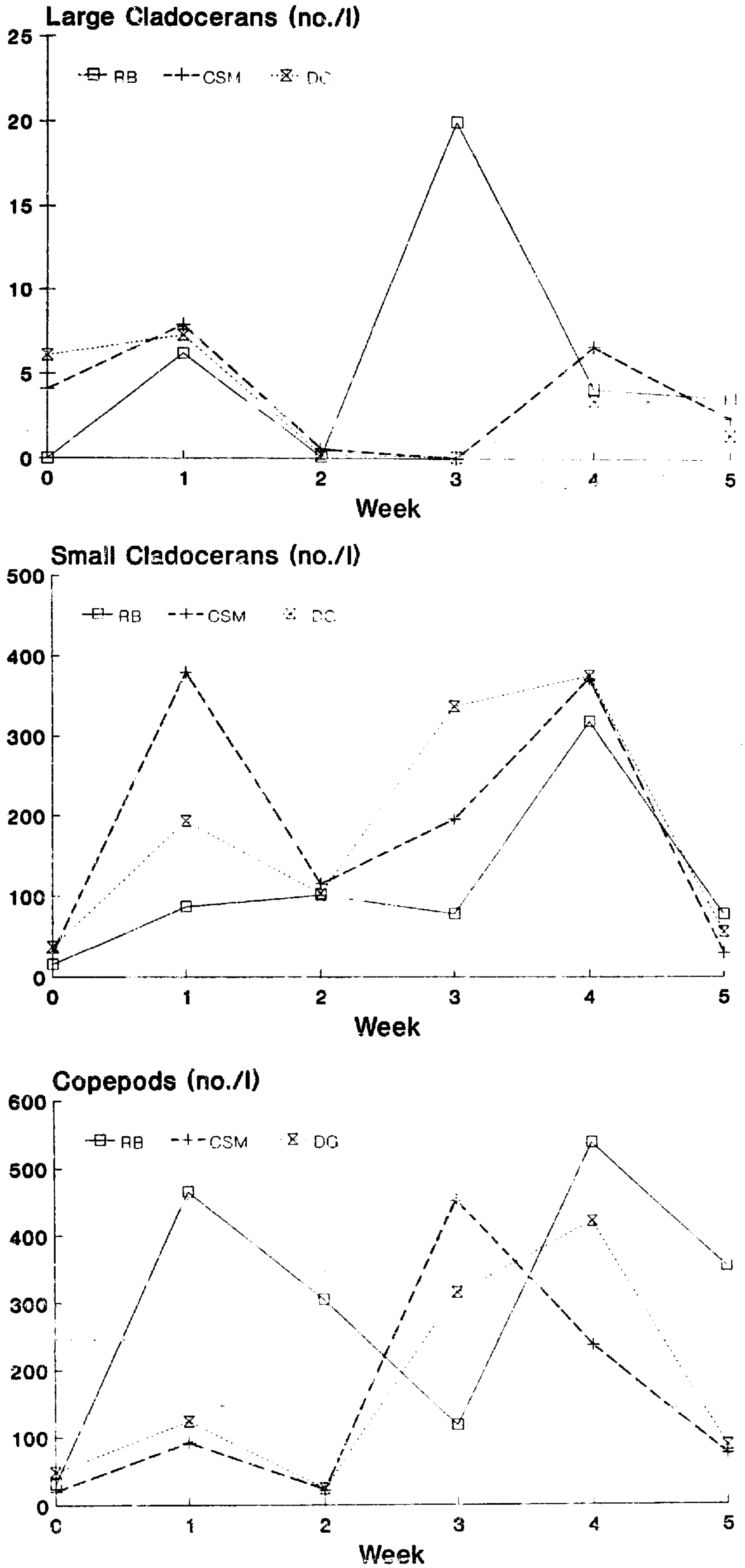

Fig. 5. Densities of large and small cladocerans (no./l) and copepods (no./l) in ponds fertilized with rice bran (RB), cottonseed meal (CSM), or distiller's grain (DG).

TABLE 4

Mean percentages of food items found in stomachs of paddlefish (r_i), concurrently collected pond samples (p_i), and mean linear selection index values (L) for six zooplankton groups utilized by paddlefish stocked at 61 775/ha in 0.02-ha ponds

Week	Treatment[1]	Fish length (mm)	n_r[2]	n_p[3]	Small cladocerans			Large cladocerans			Copepods		
					r_i	p_i[4]	L	r_i	p_i[4]	L	r_i	p_i	L
1	RB	21.0±2.2	20	2019	0	4	−0.04	100	0	1.00	0	22	−0.22
	CSM	22.1±0.5	22	1872	0	20	−0.20	100	0	1.00	0	5	−0.05
	DG	21.7±1.0	24	980	0	13	−0.13	100	0	1.00	0	12	−0.12
2	RB	38.0±6.3	36	2271	0	13	−0.13	97	0	0.97	3	17	−0.14
	CSM	40.8±1.8	61	1294	0	8	−0.08	100	0	1.00	0	2	−0.02
	DG	44.5±1.4	48	1172	0	11	−0.11	100	0	1.00	0	2	−0.02
3	RB	70.3±6.6	191	3099	0	4	−0.04	100	1	0.99	0	10	−0.10
	CSM	79.6±3.0	116	2667	25	0	0.25	78	0	0.78	0	15	−0.15
	DG	78.3±2.1	43	2911	13	11	0.02	82	0	0.82	3	12	−0.09
4	RB	108.2±5.5	25.6	5024	11	6	0.05	45	0	0.45	43	11	0.32
	CSM	96.0±9.0	21.0	5800	4	7	−0.03	68	0	0.68	23	4	0.19
	DG	94.1±6.5	40.0	3082	25	0	0.25	57	0	0.57	17	14	0.03
5	RB	115.2±4.0	107	3564	6	3	0.03	54	0	0.54	39	8	0.31
	CSM	99.2±7.3	53	3087	6	1	0.05	88	0	0.88	5	1	0.04
	DG	103.0±6.3	67	2660	8	3	0.05	45	0	0.45	46	3	0.43
6	RB	123.8±8.1	1600	4162	26	2	0.24	5	0	0.04	47	4	0.43
	CSM	106.2±10.6	1375	3812	27	1	0.26	19	0	0.19	9	2	0.07
	DG	112.5±6.0	7.4	2179	0	3	−0.03	28	0	0.28	36	2	0.34

[1]Treatments = rice bran (RB), cottonseed meal (CSM), and distiller's dried grain (DG).
[2]n_r = total number/organism from stomachs of three sampled fish.
[3]n_p = total number potential prey species/l water collected from pond.
[4]Zero represents values less than 0.5%.

fertilized with CSM or DG. Increased numbers of large cladoceran ephippial females were first noted on week 2 in ponds fertilized with CSM. Dominant large cladocerans identified in the treatments were *Daphnia pulex*, *D. catawba*, *Simocephalus serralatus*, and *Scaphaleberis kingi*. Small cladoceran (0.3–0.6 mm) densities were lower ($P > 0.05$) in ponds fertilized with RB than with CSM or DG throughout most of the study (Fig. 5). Dominant small cladocerans were *Bosmina longirostris* and *Chydorus sphaericus*. Copepods demonstrated similar trends ($P > 0.05$) in population densities, though subject to wide fluctuations (Fig. 5).

Zooplankton selection by fish

Proportions of prey groups in paddlefish stomachs to prey groups in the ponds followed similar trends through week 2 (Table 4). Paddlefish (<50 mm) consumed large cladocerans (*Daphnia* spp.) almost exclusively. In ponds fertilized with CSM or DG, fish began to consume small cladocerans during week 3. The number of large cladocerans in the stomachs of paddlefish in ponds fertilized with RB was two and six times greater than in the stomachs of paddlefish in ponds fertilized with CSM or DG, respectively. In week 4, there was a drastic decline in the total number of zooplankton found in the stomachs of paddlefish (n_r) in the ponds fertilized with RB or CSM; however, large cladocerans continued to be selected more frequently than other zooplankton groups. Between weeks 5 and 6, there was the greatest increase in total number of zooplankton and in consumption of other zooplankton groups (primarily small cladocerans and copepods) for fish in ponds fertilized with RB or CSM.

DISCUSSION

Previous research with paddlefish fingerling production has shown that a combination of various types of agricultural products, by-products and animal manure as organic fertilizers coupled with inoculations with large cladocerans would promote zooplankton production to provide fish yields of 125 kg/ha (Semmens, 1982). The results from this study indicate that RB, CSM, or DG applied with an inorganic fertilizer, inoculation with large cladocerans (*Daphnia* spp.), and air-lift pumps gave good growth (106–123 mm TL) high survival (60–80%) and higher net yields (150–285 kg/ha) after 40 d than previously reported for paddlefish fingerlings.

The best organic fertilizer for production of fingerling paddlefish (≥ 120 mm TL) appears to be RB. Paddlefish in ponds fertilized with RB supported the fastest growing, heaviest fish at a survival rate 35% higher than has been reported with other organic fertilizers (Semmens, 1982). Their average length was greater than 120 mm TL, indicating the fish converted quicker to a filter-feeding mode (which increases its feeding efficiency) (Michaletz et al., 1982) than the smaller fish (<120 mm TL) produced in ponds fertilized with CSM or DG. Zooplankton density was highest throughout most of the culture period in ponds fertilized with RB. Santiago et al. (1989) reported that RB promoted the highest zooplankton density in milkfish ponds, but served poorly as fish feed. De Pauw et al. (1981) found RB to be an excellent food for large cladocerans.

Ponds fertilized with CSM produced the smallest fish. Barkoh (1988) found cottonseed meal did not support parthenogenetic reproduction of *Daphnia* in laboratory culture. Ephippial females of *Daphnia* spp. were first noted in ponds fertilized with CSM during week 2, possibly indicating a stress response by the *Daphnia* to environmental conditions (Ivleva, 1969). It is also possible the fish fed directly on CSM Herman (1970) reported dietary levels of 0.03% free gossypol suppresses growth rate in rainbow trout. The CSM used in this study contained 0.1% free gossypol. Robinette (1981) also reported that dietary levels of 20% or more cottonseed meal in channel catfish diets causes gossypol toxicity.

Paddlefish in ponds fertilized with DG grew faster and heavier than fish in ponds fertilized with CSM; even though, zooplankton density and large cladoceran consumption were generally less in ponds fertilized with DG than ponds with CSM. It is possible that the fish consumed DG particles as a diet supplementation when cladocerans were less available. Kohler (1987) found that golden shiners (*Notemigonus chrysoleucas*), a planktophagous fish, were capable of consuming DG particulates from the water column.

Water quality was generally better in ponds fertilized with RB than in ponds fertilized with CSM or DG. Ponds fertilized with CSM or DG had higher levels of ammonia and nitrite than ponds fertilized with RB. The mortalities observed in some of the ponds fertilized with CSM or DG between weeks 3 and 4 suggests that the level of nitrite and ammonia present could have been harmful to the paddlefish. However, no studies have been conducted to assess nitrite and ammonia toxicity levels for paddlefish fingerlings. Subacute water quality problems could possibly explain the decrease in fish growth rate (2.3 mm/d) in ponds fertilized with DG or CSM compared to fish (5.4 mm/d) in ponds fertilized with RB. RB also produced a brown color in the water decreasing the secchi disk visibility, reducing sunlight penetration, and filamentous algae. The presence of filamentous algae has been observed to be detrimental to paddlefish survival (S.D. Mims, unpublished data, 1988).

The production of fingerling paddlefish (> 120 mm TL) in 40 d appears possible using RB and an inorganic fertilizer in aerated ponds inoculated with large cladocerans. The results of this study indicate that RB should be considered the standard organic fertilizer for paddlefish production. For consistent production of paddlefish, large cladocerans must be available during the 2 weeks after paddlefish are stocked. Thereafter, paddlefish can feed on less preferred food items such as small cladocerans and chironomids (Michaletz et al., 1982). Growth rates of > 2.4 mm/d would indicate preferred food items are available. This is in agreement with Michaletz et al. (1982) who reported that large cladocerans must be available for rapid growth of young paddlefish (average 2.4 mm/d).

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