# Use of Pond Effluent for Irrigation in an Integrated Crop/Aquaculture System

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## Abstract

Kenya's annual production from aquaculture is estimated at 1,100 Mg, the largest portion of this being harvested from fish ponds. The value of pond effluents in flood irrigation of crops has been demonstrated, but little research has addressed use of pond water in more efficient systems such as drip irrigation of high-value vegetable crops. A field experiment was conducted on a vertisol at Sagana, Kenya, to determine the suitability of polyculture (tilapia (*Tilapia aureus*) and African catfish (*Clarias gariepinus*)) fish-pond effluent for drip irrigation of french bean (*Phaseolus vulgaris* cv. Samantha). Treatments included nonirrigated, unfertilized (-I -F); nonirrigated, fertilized (-I +F); irrigated with canal water, unfertilized (+I -F); irrigated with canal water, fertilized (+I +F); irrigated with fish pond effluent, unfertilized (+P -F); and irrigated with equal parts canal and pond water, unfertilized (+IP -F). Canal water supplied to polyculture production ponds and to treatments +I -F, +I +F, and +P -F contained 0.49 and 0.04 mg $l^{-1}$ of nitrogen (N) and phosphorus (P), respectively. For treatments utilizing fish-pond effluent, water was transferred from nearby polyculture ponds that received 20 kg N $ha^{-1}$ $wk^{-1}$ and 8 kg P $ha^{-1}$ $wk^{-1}$ over a 17-week cycle. Pond water contained higher concentrations of N (6.03 mg $kg^{-1}$) and P (3.89 mg $kg^{-1}$) than canal water. French bean harvest began 46 days after planting and continued for 28 days. Significant differences were observed among treatments ($P \leq 0.001$) with -I -F yielding 1.2 Mg fresh beans $ha^{-1}$, and +I +F providing the highest yields: 9.1 Mg fresh beans $ha^{-1}$. Irrigation alone (+I -F) resulted in 7.7 Mg fresh beans $ha^{-1}$ with stepwise yield decline as fish-pond water was substituted for canal water: +IP -F and +P -F yielded 6.1 and 4.3 Mg fresh beans $ha^{-1}$, respectively. Yield decline with increasing amounts of pond effluent may be owing to particulates that clog drip line emitters. The 41% yield decline from pond-water substitution represents an economic loss of KSh 89,850 $ha^{-1}$ (≈US $1,404). Given the potentially high N and P concentrations of fish-pond effluent, its direct discharge into water bodies should be discouraged. Either pre-treatment filtration or alternative irrigation methods are required before advantage may be obtained from application of nutrient-enriched pond water.

## Introduction

In Kenya there are approximately 46,000 fish ponds producing about 1,100 Mg of fish annually (Government of Kenya, 1997). Fertilizers are applied to ponds to increase inorganic nutrient concentrations that favor phytoplankton growth, enhancing production of fish and crustaceans (Boyd, 1990). During harvesting, ponds are drained to levels where fish can be recovered via nets. A result of pond draining is effluent discharge (Sumari, 1982). Such effluents are often allowed to run into natural waterways. Effluents from fertilized ponds have relatively high nutrient concentrations and can be potential sources of pollution and eutrophication for receiving waters.

Pond effluents have been applied to crops as irrigation water (Prinsloo and Scoonbee, 1987; Al-Jaloud et al., 1993; Hussein and Al-Jaloud, 1995). Hussein and Al-Jaloud (1995) report wheat grain yields ranging from 770 to 5,010 kg $ha^{-1}$ with well water and 2,140 to 5,790 kg $ha^{-1}$ with aquaculture effluent. Improved water use efficiency (WUE) was also reported with aquaculture-effluent-irrigated crops having a WUE of 11 to 30 kg $ha^{-1}$ $mm^{-1}$, whereas well-water treatments had a WUE of 7 to 22 kg $ha^{-1}$ $mm^{-1}$. Grain yield and WUE obtained with well water combined with 75 to 100% of the nitrogen requirement as fertilizer were comparable to treatments irrigated with aquacultural effluents combined with 25 to 50% of the nitrogen requirement. These results imply that application of 150 to 225 kg N $ha^{-1}$ for well-water irrigation and 75 to 160 kg N $ha^{-1}$ for aquaculture-effluent irrigation containing 40 mg N $l^{-1}$ is sufficient for optimum grain yield and WUE. Similar results were obtained by Al-Jaloud et al. (1993).

When pond effluents are applied in arid and semi-arid environments, greater crop returns may be obtained through more efficient application methods. In Kenya, where farm ponds can also serve as water reservoirs for irrigation, drip irrigation could be profitable. Drip irrigation is a technique whereby water and fertilizers can be placed directly over the root zone through use of emitters that are calibrated for low flow rates. Drip irrigation appears most promising when water and fertilizer application is split into several events over a cropping season.

Little work has been conducted in East Africa on the use of fish-pond effluent as a source of irrigation water for high-value crops. A study was undertaken to determine the effects of irrigation with polyculture (tilapia and catfish) pond water on French bean yields.

## METHODS AND MATERIALS

The study was conducted at Sagana Fish Farm in the Central Province of Kenya. The farm lies at an elevation of 1,231 m above sea level. Rainfall at the farm ranges from 1,332 to 1,612 mm $yr^{-1}$, and daily average air temperatures range from 16.3 to 26.9°C. The water supply to the farm comes from the Ragati River. Soils at the farm are "black cotton soils" (vertisols) of volcanic origin.

One fish pond from Sagana Fish Farm was selected to supply effluent for this experiment. The pond was fertilized with 8 kg P $ha^{-1}$ as diammonium phosphate (DAP) during a 17-week period prior to stocking. The pond was then stocked with tilapia (*Tilapia aureus*) and African catfish (*Clarias gariepinus*). Subsequently, nitrogen was supplied to the pond weekly at a rate of 10 kg $ha^{-1}$.

Eighteen field plots measuring 10 x 6 m were prepared on land previously under star grass *(Digituara scalarum)*. Plots were hand-tilled and hand-harrowed sufficiently for planting French bean. In October 1998, plots were planted with French bean (var. Samantha) at a spacing of 0.6 x 0.1 m.

The experiment design was an incomplete factorial arranged as a randomized complete block with six treatments replicated three times. Treatments consisted of: nonirrigated, unfertilized (-I -F); nonirrigated, fertilized (-I +F); irrigated with canal water, unfertilized (+I -F); irrigated with canal water, fertilized (+I +F); irrigated with fish-pond effluent, unfertilized (+P -F); and irrigated with equal parts canal and pond water, unfertilized (+IP -F). At planting, DAP (200 kg $ha^{-1}$) was applied to treatments receiving fertilizer. These treatments received an additional 200 kg $ha^{-1}$ of calcium-nitrate as top dressing after bean emergence. Plots receiving irrigation water were fitted with garden drip irrigation systems. A 10-l distribution bucket suspended on a post held water (canal or pond) to irrigate individual plots receiving irrigation treatments. Irrigated treatments received 0.03 mm water $d^{-1}$ over a growing season of 74 days.

French bean harvest began 46 days after planting, and continued for 28 days. Fresh and dry weight of bean pods and total biomass dry weight (dry pods, leaves, and stems) were recorded. Analyses of variance were performed to determine variation in French bean fresh and dry biomass owing to treatments.

## RESULTS

Table 1 provides information on nitrogen and phosphorus concentrations in water used for irrigation from the canal and the polyculture pond. Upon introduction of canal water into the pond and subsequent fertilization, the nitrogen and phosphorus contents in the pond water increased.

French bean was in the field from early November to early February. A total of 28.8 $m^3$ water was withdrawn from the pond for irrigation of French bean plots. With an irrigation addition of 0.03 mm $d^{-1}$, 2.4 kg N $ha^{-1}$ and 1.6 kg P $ha^{-1}$ were supplied to the root zone for the whole season. This input was extremely low and equivalent to 4.8% and 3.2% of the recommended rates for nitrogen and phosphorus, respectively.

Fresh and dry weight of bean pods and above-ground dry matter yield of bean plants are shown in Table 2. Yields were modified by treatment ($P \leq 0.001$).

Table 1. Nitrogen and phosphorus concentrations of canal and fish-pond water used for irrigation treatments on French beans at Sagana, Kenya, in 1998. Numbers in parentheses are standard errors.

| Source | N | P |
|---|---|---|
| | (mg $l^{-1}$) | |
| Canal | 0.49 (0.13) | 0.04 (0.03) |
| Pond | 6.03 (0.58) | 3.89 (1.06) |

Table 2. Fresh bean yield, dry bean yield, and dry biomass (stem + leaf) yield of French beans as affected by irrigation and fertilizer treatments at Sagana, Kenya, in 1998. Numbers in parentheses are standard errors.

| Treatment | Fresh Bean Weight | Dry Bean Weight | Biomass Yield |
|---|---|---|---|
| | | (kg $ha^{-1}$) | |
| Nonirrigated, Unfertilized | 1,249 (701) | 116 (66) | 272 (176) |
| Nonirrigated, Fertilized | 7,284 (1,881) | 680 (175) | 1,494 (569) |
| Irrigated with Canal Water, Unfertilized | 7,704 (357) | 719 (33) | 1,214 (490) |
| Irrigated with Canal Water, Fertilized | 9,144 (2,419) | 853 (226) | 1,567 (475) |
| Irrigated with Fish Pond Effluent, Unfertilized | 6,051 (1,935) | 565 (181) | 785 (277) |
| Irrigated with Equal Parts Canal and Pond Water, Unfertilized | 4,289 (851) | 400 (79) | 640 (144) |

## DISCUSSION

The amount of water withdrawn from the fish pond and applied to the French bean plots was relatively small compared to losses from evaporation and seepage. Pond water volume reduction related to irrigation of horticulture crops can apparently be accommodated in an integrated fish/crop system.

The control treatment (-I -F) yielded 1.2 Mg $ha^{-1}$ of fresh beans; the inadequate rainfall and soil fertility may explain the low yield of this treatment. The highest bean yield, 9.1 Mg $ha^{-1}$, was observed where canal water was used for irrigation in combination with fertilizer application. Adequate amounts of moisture were attained with irrigation, while the crop received sufficient nutrition from fertilizer. Application of pond water without fertilization resulted in a yield of 4.3 Mg $ha^{-1}$. The amount of nutrients supplied by pond water over the growing season was not adequate to produce high yields. In addition, filters fitted on the drip system receiving water from the pond clogged frequently and were cleaned more often than those fitted on systems receiving water from the canal. Clogging was due to high total solids and algae in pond water. Pond water was poorly distributed along drip irrigation lines due to irregular clogging of emitters.

As pond water was substituted for canal water, the effects of the accompanying high algae and total solids concentrations increased (Table 2). There was a gradual decline in yield, with the 1:1 ratio of pond:canal water giving an intermediate yield of 6.1 Mg $ha^{-1}$. A 41% yield decline from substituting pond water for canal water resulted in an economic loss of KSh 75,000 $ha^{-1}$ if French beans are valued at KSh 30 $kg^{-1}$.

## ANTICIPATED BENEFITS

Application of chemical fertilizers in ponds and activities of fish increase the nutrient concentration of pond water. Application of pond water to crops during fish grow-out is feasible, but filtration will be required if it is to be delivered through a drip irrigation system. Nutrient enrichment of pond water during aquaculture production is insufficient to meet crop nutrient demand unless the water is applied in larger amounts. Larger amounts of water may cause negative effects including impaired soil aeration.

## LITERATURE CITED

Al-Jaloud, A.A., G. Hussain, A.A. Alsadon, A.Q. Siddiqui, and A. Al-Najada, 1993. Use of aquaculture effluent as a supplemental source of nitrogen fertilizer to a wheat crop. Arid Soil Res. Rehab., 7(3):233–241.

Boyd, C.E., 1990. Water Quality in Ponds for Fish Culture. Alabama Agricultural Experiment Station, Auburn University, Alabama, 482 pp.

Government of Kenya, 1997. National Fisheries Statistics Bulletin. Department of Fisheries, Ministry of Natural Resources, Nairobi, Kenya.

Hussein, G. and A.A. Al-Jaloud, 1995. Effects of irrigation and nitrogen on water use efficiency of wheat in Saudi Arabia, Agric. Water Manage., 27(2):143–153.

Prinsloo, J.F. and H.J. Schoonbee, 1987. Investigations into the feasibility of a duck-fish-vegetable integrated agriculture-aquaculture system for developing areas in South Africa. Water SA, 13(2):109–118.

Sumari, O., 1982. Report on fish farm effluents in Finland. In: J.S. Alabaster (Editor), Report of the EIFAC Workshop on Fish-Farm Effluents, Silkeborg, Denmark, 26–28 May 1981. European Inland Fisheries Advisory Commission (EIFAC) Tech. Paper 41. FAO, Rome, pp. 21–28.

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