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Research Application Summary

# Effect of application of aquaculture effluent on nutrient uptake and grain yield of the common bean

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## Abstract

A study was conducted to evaluate the fertilizer value of aquaculture effluent from African catfish (*Clarius glerepenus*) with respect to common bean (*Phaseolus vulgaris*). The study i) determined the crop nutrient value of aquaculture effluent and ii) the effect of using aquaculture effluents on the yield of common bean. A field study was conducted in Tende innovation farm, an aquaculture farm located in Wakiso district in central Uganda. Beans were planted in a split plot design and subjected to four water source treatments. These were: catfish hatchery water (Hw), catfish pond water (Pw), rain water (Rw) and lake water (Lw). Water, plant, grain, and soil samples from the four treatments were collected and analysed for nitrogen and phosphorus content. Results showed a significant difference in the total nitrogen (TN) and total phosphorus (TP) in the water treatments ($p<0.05$). The Pw and Hw treatments contained higher amounts of TN and TP. Significant effects ($p<0.05$) on nutrient uptake were also observed between treatments in the shoots, roots and grains. Application of Pw and Hw significantly ($p<0.05$) increased bean yield. It is therefore recommended that aquaculture wastewater based on its nutrient level load can be utilized as an important ameliorant for improving nutrient availability in irrigated agriculture particularly in horticultural crops that require nitrogen and phosphorus amendments.

Key words: Aquaculture waste water, irrigation, *Phaseolus vulgaris*, soil

## Résumé

La présente étude a été menée pour évaluer la valeur fertilisante des effluents aquacoles du poisson-chat africain (*Clarius glerepenus*) par rapport au haricot (*Phaseolus vulgaris*). L'étude i) a déterminé la valeur nutritive des cultures de l'effluent de l'aquaculture et ii) l'effet de l'utilisation des effluents de l'aquaculture sur le rendement du haricot. Les travaux de terrain ont été menés à la ferme d'innovation de Tende, une ferme aquacole située dans le district de Wakiso, au centre de l'Ouganda. Les graines du haricot ont été semées suivant un dispositif de split plot et soumises à quatre traitements de source d'eau à savoir: l'eau d'éclosion de poisson-chat (Hw), l'eau d'étang de poisson-chat (Pw), l'eau de pluie (Rw) et l'eau de lac (Lw). Des échantillons d'eau, de plantes, de graines et de sol provenant des quatre traitements ont été collectés et analysés pour leur teneur en azote et en phosphore. Les résultats ont montré une différence significative de l'azote total et du phosphore total entre les traitements de l'eau ($p < 0,05$). Les traitements Pw et Hw avaient des quantités plus d'azote et de phosphore élevées. Des effets significatifs ($p < 0,05$) sur l'absorption des nutriments ont également été notés entre les traitements au niveau des pousses, des racines et des grains. L'application des eaux d'éclosion et d'étang de poisson-chat a augmenté de manière significative ($p < 0,05$) le rendement en haricot. Il est donc recommandé d'utiliser les eaux usées d'aquaculture selon leur charge en éléments nutritifs pour améliorer la disponibilité des nutriments dans les systèmes d'agriculture irriguée, en particulier pour les cultures horticoles qui nécessitent des amendements d'azote et de phosphore.

Mots clés: Eaux usées d'aquaculture, irrigation, *Phaseolus vulgaris*, sol

## Background

Soil fertility decline is one of the major causes of spiraling levels of food insecurity and abject poverty in Uganda (FAO, 2008). Although mineral fertiliser use was adopted swiftly in the greater part of Asia leading to the famous green revolution in the 1970s (Dawson *et al.*, 2016; Fischer, 2016) efforts to emulate this in Africa have so far not succeeded (Otsuka and Kalirajan, 2006). This is due to a milliard of unique factors most especially the global spiraling mineral fertiliser costs which are prohibitive (Omamo, 2003; Westlake, 1999), farmers involvement in mostly subsistence agriculture (Bekunda *et al.,* 2010) and the negative environmental impacts associated with inorganic fertiliser use (Stevenson *et al*., 2010). However, several researchers have shown a host of practical knowledge and skills on soil fertility improvement that smallholder farmers in Africa have used in soil fertility management (Jayne *et al*., 2014). Research in other parts of the world such as Brazil (Castro *et al*., 2006) and Asia (Frei and Becker, 2005) has shown that crop-fish-livestock integration is very important in the improvement of soil fertility and crop yield. The use of aquaculture waste water for crop production has been explored and successfully demonstrated as an alternative to spending money to treat aquaculture waste water before disposal. Extensive studies on the use of aquaculture effluent for fertilization of soil for the production of some crops have been carried out in sub-Saharan Africa (Prein, 2002; Sakamoto *et al*., 2009). In Uganda however, studies involving the use of aquaculture effluent for crop production have not been done and thus the country has not exploited this resource for crop production. This study was therefore carried out to determine the influence of aquaculture effluent on crop production using common beans.

## Literature summary

Aquaculture waste water has been shown to contain sufficient amounts of nitrogen and potassium needed in the production of crops and has been proven to supply the major plant nutrients (Herath and Satoh, 2015; Herbeck *et al*., 2013) which can be used for nourishment of crops. The majority of these studies achieved positive results on crop yields and they have demonstrated success of aquaculture effluent as a fertilizer for agricultural crops.

In Uganda, in 2013/14 fishing accounted for 5.1% of the agriculture sector gross added value (NDP II). However, several aquaculture farms have since mushroomed with several adjacent to Lake Victoria and in Lake Victoria waters. However, there is limited research in the country to provide evidence and possibilities that aquaculture waste water enhances crop yields and soil properties. There is a dearth of knowledge and information with regard to the effect of the use of aquaculture waste water either as a soil amendment or as an irrigation component to salvage crops during periods of moisture deficit in Uganda. Yet, the use of aquaculture effluents for production of crops in some parts of the world has shown positive results. This may offer alternative strategies for maintaining and improving soil productivity in SSA to ensure that the food system can keep pace with the growing demand in the face of soil fertility decline. A review of literature revealed that there is scarce information available regarding the effects of aquaculture effluents on the yield and nutrient uptake of beans in Uganda, and hence, need for this study.

## Study description

The study adopted a split - split plot experimental design, with 10x12 m plots, and four water treatments namely; hatchery water (Hw), rain water (Rw), lake water (Lw), and pond water (Pw). Each treatment was replicated three time and common bean (*Phaseolus vulgaris*) was selected as the experimental crop. Water from each source was pumped from the reservoirs into specific tanks installed at the experimental site. Beans were planted in rows at a spacing of 30 x 10 cm. One bean seed was planted per hole. Two irrigation reservoirs: one to collect water discharged from the pond and another to collect water discharged from the fish hatchery were constructed. Electric powered pumps were used to discharge water from the reservoirs into elevated black plastic tanks of capacity 1 $m^3$ stationed at the experimental site. Lake water was drawn by pump directly from the lake into an elevated tank. The water from the tank was used to supply the plots through a drip irrigation system with 5 mm diameter pipes running along the crop rows. Sand filters were placed at the water exit points of each reservoir to minimize cases of clogging of pipes. An equal volume of irrigation water supplied every two days of no rain. The water used for irrigation was estimated using an analogue volume flow meter attached to each tank outlet of water.

Weeding was done once between the fourth and fifth week after planting (WAP). Beans were planted twice, first in July 2013 and the second in March 2014. After the first season harvest, tilling of land was done with caution to minimize cross plot contamination of soils. Beans were planted again in the next season with the same treatments on the same plots. At the end of each of the two experimental seasons, grain yield from the different water treatments was determined. Water samples from the four treatments during the experimental period were collected every two weeks from the tanks and analysed for total nitrogen (N) and total phosphorus (P). Data were collected from plants twice; at flowering and at physiological maturity. At flowering, three point areas each measuring 0.25$m^2$ were demarcated along the diagonal of each plot. All the plants within the demarcated areas were watered, uprooted and bulked for each plot and prepared for dry matter analysis. The shoots and roots were oven dried for 2-3 days at $65^0$C. Each of the dried samples was weighed. The samples were then ground and 0.25g of each digested for analysis of the nitrogen (N) and phosphorus (P). At physiological maturity, an area measuring 1 $m^2$ was demarcated at the center of each plot and all the bean plants in the area uprooted, counted and bulked. The total number of pods and seeds from the bulked sample was also counted and recorded. The bean seeds (grains) were then weighed and collected into labeled polythene bags per plot and transported to Makerere University Soil Science Laboratory for total nitrogen and total phosphorus content determination. The grains were then oven dried for 2 days at $70^0$C and weighed. For each replicate 0.25 g sample was ground and digested to determine its total nitrogen (N), and total phosphorus (P) content. The same procedure was repeated during the second season of planting. Nine soil samples were collected during the study for analysis. A composite soil sample from a depth of 0-30 cm was first collected from the experimental site before the first planting of beans. Then, during each of the two harvest seasons, a composite soil sample was collected from each treatment. The soil samples were analysed to determine the changes in soil total nitrogen and available phosphorus during the experimental period.

## Results and discussions

Pond water (Pw) had considerably higher concentrations of TN and TP (Table 1). The observed difference could be attributed to relatively higher level of input and application of artificial fish feeds and fertilisers into the fish ponds and fish hatchery systems in a bid to promote fish growth. According to Boyd. (2015), artificial fish feeds have a high concentration of nutrients such as N and P.

**Table 1. N and P characteristics of irrigation water and rain water**

| Water source | Total nitrogen (TN) | Total phosphorous (TP) |
|---|---|---|
| Rain water ($mgl^{-1}$) | 0.047 | 0.0089 |
| Lake water ($mgl^{-1}$) | 2.77 | 0.21 |
| Hatchery water ($mgl^{-1}$) | 91.74 | 6.71 |
| Pond water ($mgl^{-1}$) | 109.9 | 7.84 |
| $P<0.05$ | 0.013 | 0.047 |

Beans irrigated with hatchery and pond water had a significantly higher concentration of N in the shoots and roots compared to lake water and rain water (Tables 1 and 2). Shoot P was also significantly higher in Hw. These patterns could be due to the higher nutrient concentrations of TN and TP in the pond and hatchery water arising from fish feed and fecal matter. Recent studies by Imran *et al*. (2013) and Postma *et al*. (2014) have opined that when primary nutrients are readily available within the root zone, plants respond by rapidly up-taking to facilitate biomass accumulation and yield. This seems to be the case in this study. Further, biomass accumulation (roots and shoots) seemed to facilitate higher grain yield that is closely linked to the availability of primary nutrients (N and P) in the hatchery and pond water (Table 3). The high relative yield observed in this study also indicates that the foliage was within threshold to allow seeding in the beans. In their study, Bruning

**Table 2. N and P in bean shoots at flowering in the four treatments**

| N, P content | Hw | Lw | Pw | Rw | P (0.05) |
|---|---|---|---|---|---|
| Shoot N (%) | 3.595 ± 0.656[a] | 3.596 ± 0.737[b] | 3.614 ± 0.654[a] | 3.519 ± 0.743[c] | <.001 |
| Shoot P (ppm) | 0.553 ± 0.0535[a] | 0.541 ± 0.117[b] | 0.517 ± 0.087[b] | 0.523 ± 0.139[c] | <.001 |

Values followed by the same letters in a row are not significantly different at P < .05; N.s.: not significant

**Table 3. N and P in bean grains at harvest in the four treatments**

| N, P Content | Hw | Lw | Pw | Rw | P (0.05) |
|---|---|---|---|---|---|
| Grain N (%) | 3.623 ± 0.360[a] | 3.78 ± 0.237[b] | 3.5 ± 0.240[b] | 3.572 ± 0.201[b] | 0.033 |
| Grain P (ppm) | 0.614 ± 0.07 | 0.656 ± 0.0535 | 0.594 ± 0.099 | 0.600 ± 0.105 | Ns |

Values followed by the same letters in a row are not significantly different at P < .05; N.s.: not significant

and Rozema (2013) established that where nutrients such as N and P are readily available legumes such as beans and cow pea tend to have higher yields compared to areas with limited primary nutrient availability.

The findings of this study showed that all plots used for the experiment increased in soil total nitrogen and available phosphorus concentration over the experimental time period. However, plots irrigated with hatchery and pond water had higher concentrations of total Nitrogen. There was a significant difference in the available Phosphorus of soils from the different treatments. On the other side increase in total nitrogen in all the treatments including rain fed plots could have resulted from the fact that being a legume, beans are efficient nitrogen fixers (Caixeta-Franco *et al*., 2001). However, these results also reveal the underlying fact that soil is a good media for nutrient retention and thereby facilitates *insitu* treatment of effluents before it's discharged into open water systems. Whereas this result may not be unique as earlier studies have identified the unique attributes of soil in treating waste water (Abegunrin *et al*., 2016; Zipf *et al.,* 2016); it provides a strong basis for fish-crop farming integration thereby achieving multiple benefits and strengthening resource use efficiency. Application of aquaculture effluent on land was observed to increase soil nutrient concentration in the plots that were particularly irrigated with hatchery and pond water. This also showed that aquaculture effluent can be an important source of soil amendment for regenerating and improving soils that have deficiency in N and P nutrient concentrations.

This study shows that aquaculture effluents do contain a considerable amount of primary nutrients that have two contrasting relevance; (i) if directly discharged into the environment particularly to the adjacent open lakes they could cause environmental pollution and can increase lake eutrophication thereby affecting the fisheries, and (ii) They can contribute to increase on-farm productivity when appropriately used.

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