Aquaculture 465 (2016) 172–178

Contents lists available at ScienceDirect

Aquaculture

journal homepage: www.elsevier.com/locate/aquaculture

Increasing fish farm profitability through aquaculture best management practice training in Egypt

Malcolm Dickson [a,*], Ahmed Nasr-Allah [a], Diaa Kenawy [a], Froukje Kruijssen [b]

[a] WorldFish, Abbassa, Abou Hammad, Sharkia 44662, Egypt
[b] KIT, Mauritskade 63, 1092 AD Amsterdam, the Netherlands

ARTICLE INFO

Article history:
Received 17 May 2016
Received in revised form 21 August 2016
Accepted 8 September 2016
Available online 13 September 2016

Keywords:
Aquaculture
Egypt
Tilapia
Best management practices
Training-of-trainers
Profits
Feed efficiency

ABSTRACT

Egyptian aquaculture production has grown rapidly to over one million tons per year so that it now provides most of the country's fish supply. However, Egyptian fish farmers have received little extension advice or training. An intervention starting in 2012 aimed to address this gap by providing best management practice (BMP) training for pondbased tilapia monoculture and tilapia-mullet polyculture fish farmers. A series of field-based training modules were developed and designed with the participation of leading fish farmers and delivered through private sector farmer-trainers to over 2400 fish farm owners and managers. This paper reports on the results of an impact assessment survey carried out in 2015 comparing fish farm performance, production and profitability in randomly selected farms where the manager had received and was applying the principles of BMP training (BMP) and farms where the manager had not received IEIDEAS project training (control). The results show that although the two groups were very similar in terms of general farm characteristics, BMP farms were more likely to practice tilapia-mullet polyculture than monoculture of tilapia. The main BMP training messages apparent in the results were improved feed and fertilizer management. This resulted in more efficient food conversion ratios in BMP farms compared to control farms. Average fish yields and values were similar between the two groups, although BMP farms produced less small-sized tilapia and more mullet than the control farms. Lower feed costs resulted in significantly lower operating costs in BMP farms compared to control farms, whereas fixed costs were similar for the two groups. Average net profits were significantly higher in BMP farms compared to control farms equivalent to additional profits of over $15,000 for an average farm size of 7.5 hectares. Taking into account the number of farmers trained and BMP adoption rates suggests that $18.9 million additional profits were generated through the intervention in 2014. The results demonstrate that fish farms in mature aquaculture systems can benefit significantly from the adoption of improved farm management practices suggesting that similar approaches, including field-based BMP training and the use of private sector farmer-trainers should be used to accelerate the development of nascent aquaculture sectors in other parts of Africa.

Statement of relevance: While it is often assumed that training will benefit fish farmers the true economic benefits have rarely been documented. This research demonstrates clear improvements in the profitability of Egyptian fish farmers following best management practice training.

1. Introduction

Aquaculture production has risen rapidly in Egypt since the early 1980's when it was made a priority sector for development by the government. Large areas of land were set aside for aquaculture development on the southern edges of the Nile Delta lakes, Manzala, Burullus Mariout and Edku as well as the inland Lake Quaron. Feed mills, hatcheries and research farms were established along with an institutional framework including a new commercially focused agency, the General Authority for Fisheries Resources Development under the Ministry of Agriculture and Land Reclamation, while key staff were trained in pond aquaculture techniques in the United States (El-Gayar, 2003). Pond-based aquaculture of tilapia and mullet was highly profitable which resulted in private-sector investment, and total aquaculture production grew from only 19 thousand tons per year (t/yr) in 1980 to 340 thousand t/yr in 2000, reaching an estimated total of 1.137 million t/yr in 2014. Aquaculture represented 77% of total Egyptian fish production in 2014 compared to only 54% in 2004 (GAFRD, 2016). Eighty-five percent of aquaculture production comes from ponds, concentrated in discrete aquaculture zones covering 115,000 ha close to the Nile Delta lakes where land is leased to, or is owned by fish farms, supplied with water from canals draining from agricultural irrigation systems while

* Corresponding author.
E-mail addresses: m.dickson@cgiar.org (M. Dickson), a.allah@cgiar.org (A. Nasr-Allah), d.kenawy@cgiar.org (D. Kenawy), f.kruijssen@kit.nl (F. Kruijssen).

http://dx.doi.org/10.1016/j.aquaculture.2016.09.015
0044-8486/

the remaining 15% comes from fish cages, rice fields and intensive farms (Nasr-Allah et al., 2012).

Although the Egyptian aquaculture sector has developed over several decades, many fish farmers have received little extension advice or training. This was recognized as a problem during a value chain analysis (VCA) of Egyptian aquaculture carried out in 2011 (Macfadyen et al., 2012) which found that fish farmers complained about declining profitability due to increasing production costs and static or declining selling prices for their fish. The VCA study recommended to increase fish farm profits by introducing the genetically improved Abbassa strain of Nile tilapia and designing and delivering best management practice training for the fish farmers. It was assumed that these actions would lead to increased aquaculture production and employment as the VCA suggested that each 100 t/yr of production resulted in 14 full-time jobs along the aquaculture value chain.

The adoption of best or better management practices (BMPs) has been widely promoted from the point of view of improving the environmental performance of fish farms and is often aligned with the introduction of certification schemes such as GlobalGAP or Aquaculture Stewardship Council (Frimpong et al., 2014). However, this approach can suffer from low adoption rates because it is viewed as an additional burden for the fish farmer, particularly when there is no obvious market advantage to participation in such schemes (Boyd et al., 2013).

In the current study, the introduction of best management practice training was designed from the start to concentrate on improving overall farm performance which was also expected to result in additional environmental benefits through improved feed efficiencies.

This approach has been supported by several authors who suggest that strategies integrating profitability and efficiency are an important factor affecting the adoption of aquaculture BMPs (Engle et al., 2005; Engle and Valderrama, 2004; Frimpong et al., 2014). Demonstrating profitability of better management practices will encourage their adoption by fish farmers, which will both further increase farm profits and protect the environment (Ansah and Frimpong, 2015; Poot-López et al., 2014). The positive outcomes of BMPs adoption include increased tilapia production, lower fish feed costs, and reduce impact of aquaculture on surrounding environment (Ansah et al., 2013; Ansah and Frimpong 2015; Klinger and Naylor, 2012; Poot-López et al., 2014).

The BMP training system applied in Egypt followed a field survey to document the dominant aquaculture practices in the main fish farming zones. A group of expert, mainly private-sector Egyptian fish farmers then participated in a planning workshop to define Egyptian aquaculture BMPs and helped to design a series of ten, short, field-based, practical training modules covering subjects from pond construction and preparation through to post-harvest handling. Some of these experts, along with other private-sector fish farmers and consultants went on to become BMP trainers, delivering field-based training in short sessions, usually delivered at the pond-side as each training module included practical demonstration of a skill. In each session they would cover two or three of the modules with a group of around ten fish farmers. The trainers were paid a small allowance to deliver the training and were encouraged to make sure that, where possible, fish farmers completed the entire course. The course evolved into 15 individual topics meaning that each fish farmer attended around five training sessions over a period of time. After a three-year implementation period, ending in December 2014, more than 3000 training sessions had been delivered across five governorates, while over 2400 fish farmers and fish farm managers had completed the 15 module BMP training course (Fig. 1; Table 1).

An impact assessment was carried out in 2015 covering the BMP training carried out in four governorates: Behera, Fayoum, Kafr El Sheikh and Sharkia. While the study focused on impacts from use of the Abbassa improved strain of Nile tilapia as well as the adoption of BMPs by fish farmers, this paper is concerned with the adoption and impacts of BMPs on fish farm incomes, production and profits only.

Fig. 1. Location of study governorates.

2. Methodology

2.1. Study methodology and approach

A farmer and fish farm database was compiled using data collected during the BMP training as well as using sales records from hatcheries disseminating seed of the Abbassa improved strain. Additional data came from databases held by the General Authority for Fish Resources Development (GAFRD) on licensed fish farms and farms that have been fined for operating without a license. The total number in the database stood at 3715 farms. The total number of fish farms in Egypt is unknown but has been estimated at between 6000 and 12,000.

A stratified random sampling framework was established with the aim of comparing results from the interventions. The groups used for comparison were as follows: (1) farms where the fish farm operator had received best management practice training (BMP or treatment) and the practices were being applied; and (2) a control group of fish farms that had no involvement with the training (control).

Farmers in the BMP group were pre-qualified for selection through a BMP adoption survey where fish farmers were asked if they had changed their practices. However, it should be noted that it was not possible to physically verify whether they had actually applied the

Table 1
Number of training sessions delivered in each governorate.

Governorate	Number of training sessions
Kafr El Sheikh	1340
Sharkia	886
Fayoum	635
Behera	382
Mineya	44

Table 2
Sample size of fish farm impact assessment interviews by governorate and treatment and control groups.

Governorate	Control	BMP	Total
Behera	12	15	27
Fayoum	14	14	28
Kafr El-Sheikh	20	31	51
Sharkia	10	22	32
Total	**56**	**82**	**138**

practices. The 70% of farmers classified as 'high adopters' (using identified thresholds) were included in the list used for random selection of impact assessment survey participants. The rationale behind this approach was that it was pointless to assess impacts if the farmers in question were not applying the recommended practices. The primary sources for identification of control group fish farms were the GAFRD databases. Selection bias was a major concern in the design of the sampling framework as access to BMP training was restricted to farmers that had connections to one of the BMP trainers. Random selection of control farms from the GAFRD database aimed to result in selection of farmers that were similar in terms of farm size, number of ponds, pond sizes and also socio-economic characteristics.

2.2. Questionnaire design and field work

The study used a structured questionnaire that focused on measuring project impact in terms of farm production, productivity and financial performance. The questionnaire was drafted in English then translated into Arabic and field tested at the WorldFish Research Center in Abbassa, Sharkia before being finalized for use in the field. The final version of the questionnaire was incorporated into KoBoCollect 1.4.3 (1039) [Open Data Kit] to enable data collection and compilation using tablets and smartphones into a database for future downloading and aggregation as necessary. Where tablets or smartphones were unavailable during the survey, hard copies of the questionnaire were used.

The study team consisted of four staff from WorldFish and two farmer trainers. The trainers provided support by identifying and interviewing pre-selected farmers, often at a central location for logistical reasons. Each farmer was interviewed separately to minimize the risk of bias in their responses. Where it was not possible to bring farmers together and particularly for control farmers, individual farm visits were carried out.

Randomized selection of interviewees meant more time was needed for data collection than was anticipated. Although the original sampling framework anticipated a total of 186 interviews (93 for each group) only 138 had been completed by early November when field data collection was terminated and farmers had started to harvest fish stocked in 2015. Table 2 shows the distribution of interviews between groups and across the study area (four governorates).

At the end of each interview, the combined data were downloaded from the KoBoCollect web site as an MS Excel file and aggregated by governorate and by group. Data were checked for validity with the interviewer responsible for completing the interview. The data were then analyzed to generate the results presented in this paper.

Data on fish sales volumes and values and on variable and fixed costs were used to construct costs and returns models for individual farms and to derive average values for control farms and BMP farms. Financial performance of the farm systems was compared by developing costs and returns tables (Macfadyen et al., 2012; Nasr-Allah et al., 2014). The main indicators of financial performance were returns above variable costs and net profits expressed as described by Jolly and Clonts (1993):

$$NP = GR - TC$$

where;NP = Net ProfitGR = Gross Revenue ($GR = P_y.\ Y$)
P_y = Unit Price of Output
Y = Quantity of OutputTC = Total Cost (US\$)TC = (TFC + TVC)
TFC = Total Fixed Cost (US\$)
TVC = Total Variable Cost (US\$) = $P_x.\ X$
P_x = Unit Price of Input
X = Quantity of Input

$$\text{Return above variable costs (operating profit)} = GR - TVC$$

$$\text{Return above total costs (net profit)} = GR - TC$$

$$\text{Apparent food conversion ratio (AFCR)} = \text{amount of food fed/total biomass harvested}$$

Calculation of the depreciation cost of equipment was computed using the straight line method (Jolly and Clonts, 1993), where annual depreciation = (Cost − Salvage Value)/Useful life and the salvage value for all equipment was assumed to be zero (Asmah, 2008).

Statistical analysis was carried out using SPSS (version 19.0) according to the method of Field (2009). Tests were performed on key dependent variables to confirm that they were normally distributed before carrying out statistical analysis. In all cases non-parametric tests (Mann-Whitney U tests) were performed to evaluate the significance of differences between means.

3. Results

3.1. General characteristics of farming practices

The social and general characteristics of control and BMP fish farmer groups are presented in Table 3. The results demonstrate that BMP farmers were slightly younger than control farmers and had smaller average family sizes compared to control groups. However, there was no significant difference in the number of years of experience between

Table 3
General fish farm characteristics and stocking practices (mean ± SE).

Farm Characteristics	Control	BMP	P-value*
Sample size	56	82	
Age of farmer (yrs)	43.4 ± 1.23	39.0 ± 1.07	**0.006**
Family size	6.2 ± 0.61	5.0 ± 0.29	**0.090**
Years in business	16.4 ± 1.03	15.3 ± 0.87	0.404
Average farm size (ha)	7.24 ± 0.89	7.96 ± 0.83	0.473
Average no. of ponds	5.8 ± 0.69	5.4 ± 0.5	0.906
Average pond size (ha)	1.25 ± 0.08	1.47 ± 0.12	0.421
Culture system:			
% practicing tilapia mono-culture	41	29	–
% practicing tilapia-mullet poly-culture	59	71	–
Average stocking rates			
Total stocking rate (no./ha)	41,805 ± 1937	38,508 ± 1494	0.595
Tilapia (no./ha)	38,759 ± 2238	33,987 ± 1564	0.184
Grey mullet (no./ha)	1266 ± 196	1294 ± 132	0.460
Thinlip mullet (no./ha)	1767 ± 396	3142 ± 294	**0.001**
Carp (no./ha)	8.5 ± 8.5	23.2 ± 15.8	0.521
Catfish (no./ha)	4.25 ± 4.25	40.6 ± 17.9	**0.093**
Average stocking size			
Tilapia (g/pc)	9.57 ± 1.7	6.35 ± 0.87	0.300
Grey mullet (g/pc)	22.2 ± 3.4	22 ± 2.8	0.555
Thinlip mullet (g/pc)	20.2 ± 2.9	17.6 ± 2	0.199
Carp (g/pc)	100	15 ± 2.9	–
Catfish (g/pc)	100	528.6 ± 130	–
Feeds and feed use			
Average level of protein in feed (%)	29.6 ± 1.27	30.8 ± 1.38	0.635
Fish feed used volume (t/ha)	14.04 ± 1.03	12.14 ± 0.82	**0.067**
Apparent FCR	1.82 ± 0.08	1.53 ± 0.06	**0.005**

* P-values indicated in bold are those significant at least at the 0.10-level.

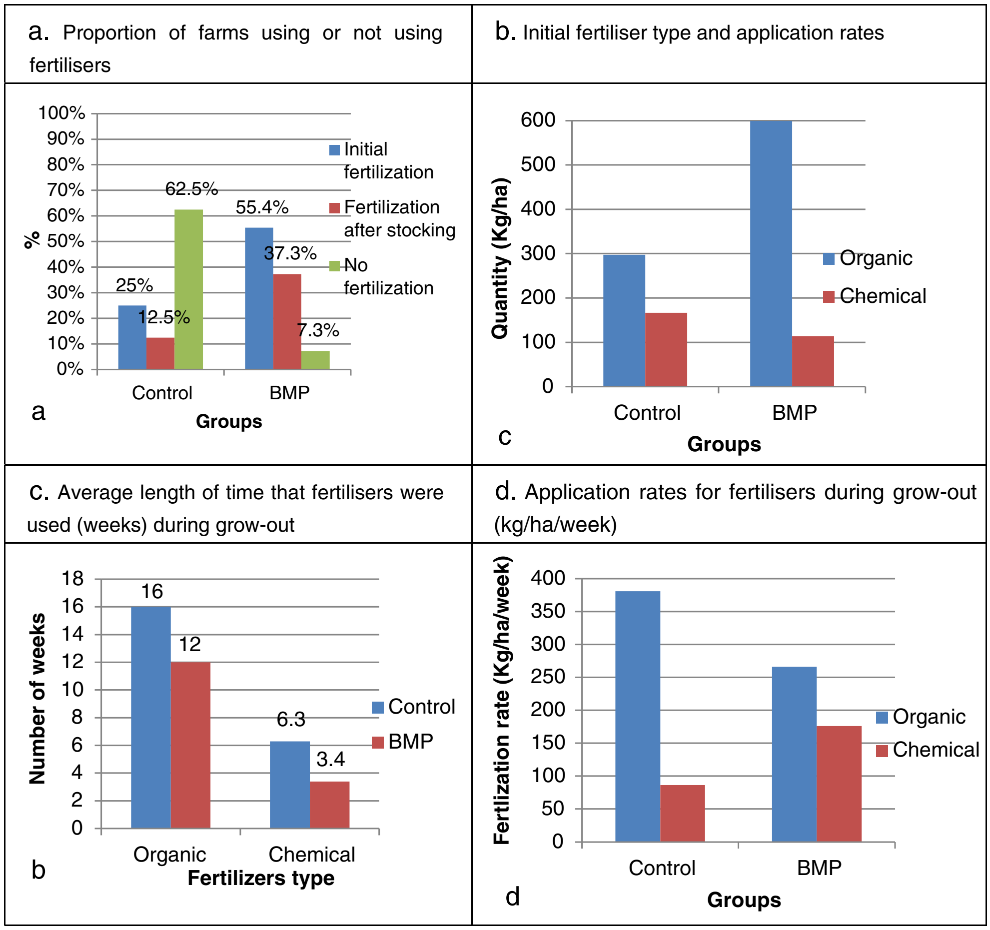

Fig. 2. Fertilization strategies and application rates and duration adopted by control and BMP farmers.

the groups, the average farm size, the average number of ponds, and average pond size. Hence, most of the main socio-economic characteristics of the treatment (BMP) and control groups were the same.

Among control farms, 41% practiced mono-culture of Nile tilapia (*Oreochromis niloticus*) while the remainder used polyculture systems with tilapia and mullet (grey mullet, *Mugil cephalus* and thin-lipped mullet, *Liza ramada*) as the main species whereas only 29% of the BMP farms practiced mono-culture of tilapia.

One of the key messages in the BMP training was to reduce overall stocking rates with the objective of harvesting more fish in the larger size grades. However, the mean total stocking rate of seed (number of fish stocked per hectare) were not significantly different between treatment and control farms. Disaggregating by species, average tilapia and grey mullet stocking rates were also not significantly different, indicating that the 'reduced stocking rate' message was only partially applied, whereas thin-lipped mullet stocking rates were significantly higher in BMP farms than in control farms. Very few farms stocked other species such as carp or catfish and when they did, the stocking rates were low.

3.2. Use of fertilizers and feeds

The effective use of fertilizers before and after stocking (recommended materials, application rates in different circumstances,

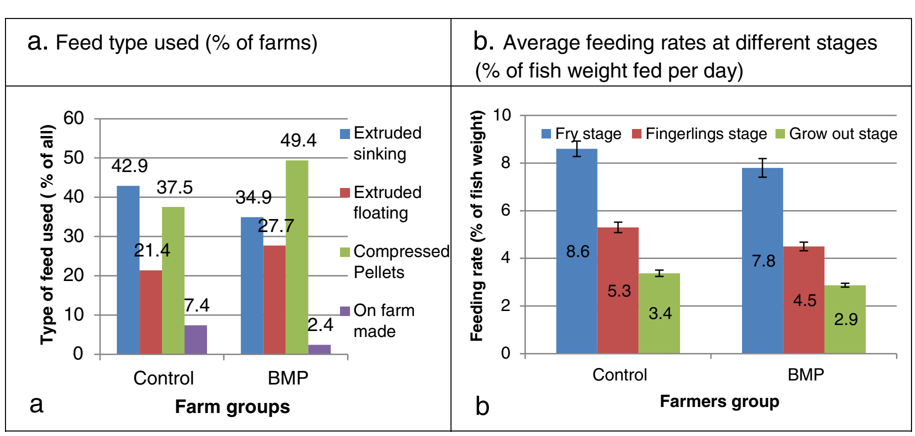

Fig. 3. Comparison of type of feed used and feeding rates for control and BMP farms.

checking plankton levels), was another key message in the BMP training. Fig. 2a shows the fertilization strategies used by control and BMP farmers. This message appears to have been applied as nearly all the BMP farms used fertilizers whereas the majority (62.5%) of control farmers did not. The concept is that pond fertilization stimulates the growth of plankton providing high quality food at minimal cost (El-Naggar et al., 2010). For the farms that carried out initial fertilization, the main fertilizer used was dried chicken manure applied at an average rate of 599 kg/ha by the BMP-trained fish farmers, compared to only 297 kg/ha on control farms (Fig. 2b). The duration of fertilizer application after the ponds were stocked and the application rates used (for farms that practiced post-stocking fertilization) are shown in Figs. 2c and d, respectively. These indicate that BMP farmers used fertilizers for a shorter time during grow-out and tended to use more organic than inorganic fertilizers than control farmers.

The BMP training focused on effective feed management as a key message recommending that close attention needs to be paid during feeding to reduce feed waste and that high quality feeds should be used rather than the cheapest. Egyptian fish farmers have the opportunity to use a wide range of different feeds from a variety of sources including farm-made mixes, conventionally pelleted feeds and extruded floating or sinking feeds (El-Sayed et al., 2015).

As shown in Fig. 3a, the proportion of farms using extruded feeds (extruded floating and extruded sinking) was similar for the two groups. However, slightly more BMP farms than control farms appeared to use conventionally pelleted (compressed) feeds and fewer BMP farms than control farms used on-farm made feeds. It should be noted that some farms used more than one type of feed.

Fig. 3b compares the average feeding rates (% of estimated fish weight applied per day) used by control and BMP farms at different stages of growth; fry, fingerlings and grow-out. This suggests that the BMP farms tended to use less feed than the control farms.

As indicated in Table 3, there was no significant difference between the average protein levels (as indicated by the feed manufacturers) of feed used by BMP and control farmers. When farmers were asked to estimate the total amount of feed used to grow their fish, the average amount used on control farms was significantly higher at 14.04 tons per hectare (t/ha) compared to 12.14 t/ha for BMP farms (Table 3).

Comparing fish yields to the amount of feed used on each farm makes it possible to derive apparent food conversion ratios (AFCR). The results (Table 3) show that AFCRs were significantly lower on BMP farms (than on control farms (1.53 and 1.82 respectively) indicating that improved feed management practices on BMP farms resulted in more efficient conversion of feed into growth of fish.

3.3. Harvest weights and fish yields

Table 4 shows the estimated average harvest sizes of fish from control and BMP farms. The results indicate that the only significant difference was between the average size of thin-lip mullet which were significantly larger at harvest on BMP farms than from control farms.

A detailed comparison of production by species and size grades is presented in Table 5. This shows that average yields were not significantly different for BMP and control farms. While this contradicted the theory of change for the training intervention which assumed that BMP trained fish farmers would produce more fish, it fits in with the detailed BMP messages which stressed efficient management, including reduced stocking rates and improved management of water, fertilization and feeding. When the yields were analyzed by species, there was no difference between the average yields of tilapia on BMP and control farms. However, disaggregating by size grades revealed that BMP farms produced significantly less grade 3 (small-sized) tilapia than control farms.

The total mullet yield for BMP farms was significantly higher than for the control group and this applied to both species as BMP farms produced significantly more thin-lip mullet and grey mullet than control fish farms.

Table 4
Average harvest weight of different species by control and BMP farms (g ± SE).

Species	Control	BMP	P-value*
Tilapia	281 ± 7.8	296 ± 7.9	0.266
Grey mullet	431 ± 22	405 ± 18	0.432
Thinlip mullet	207 ± 14	235 ± 10	**0.070**
Common carp	4000	3667 ± 882	–
Catfish	1500	2036 ± 320	–

* P-values indicated in bold are those significant at least at the 0.10-level.

Detailed average selling prices ($/kg) and revenue generated from fish sales ($/ha) are presented in Table 6. Overall, BMP farms achieved a significantly higher weighted average sales price than control farms (($1.79/kg and $1.66/kg respectively) which may, in part be due to the higher mullet yields as mullet are worth almost twice as much as tilapia. No other differences in fish selling prices were apparent.

The analysis of sales revenue indicates that average total sales were similar for BMP farms and control farms. The only significant difference was that average mullet sales revenue in BMP farms was significantly higher than in control farms ($3513 and $2047 respectively).

3.4. Enterprise budgets and profitability

Detailed comparisons of variable costs and fixed costs for control and BMP farms are shown in Tables 7 and 8. The average total operating costs for control farms was significantly higher compared to BMP farms. The lower variable costs of BMP group could be attributed to the lower feed costs in BMP farms compared to control farms. Feed costs were significantly lower in BMP farms ($6709/ha) compared to control farms ($8023/ha). Feed costs represented 79% of variable costs in control farms compared with 75.4% in BMP farms.

The second highest cost item was seed costs which were similar in BMP farms and control farms despite the higher stocking rate of mullet in BMP farms compared to control farms. Fuel and electricity costs, were slightly lower on BMP farms than on control farms while fertilizer, ice and sales commission costs were significantly higher in BMP farms than in control farms.

There were no significant differences between the average fixed costs for control farms compared to BMP farms (Table 8). Land rent contributes to around half of fixed costs for both groups with no significance difference between the groups. Repairs and maintenance and depreciation come next in order of fixed costs, with no significance differences between BMP and control farms. This is consistent with expectations as short term changes in practices would not be expected to have an immediate effect on fixed investments.

Table 9 summarizes the relative financial performance of control and BMP farms. As noted above, although average revenues and fixed costs

Table 5
Comparison of average fish yields by species and size grades (t/ha/yr ± SE).

Species and grade	Control	BMP	P-value*
Tilapia premium	0.41 ± 0.16	0.51 ± 0.24	0.435
Tilapia super	4.00 ± 0.65	3.98 ± 0.39	0.325
Tilapia grade 1	2.17 ± 0.31	1.87 ± 0.24	0.343
Tilapia grade 2	0.71 ± 0.13	0.45 ± 0.07	0.290
Tilapia grade 3	0.13 ± 0.05	0.03 ± 0.01	**0.082**
All tilapia	7.42 ± 0.67	6.85 ± 0.5	0.515
Grey mullet	0.36 ± 0.07	0.46 ± 0.06	**0.060**
Thin-lip mullet	0.35 ± 0.08	0.63 ± 0.07	**0.001**
All mullets	0.71 ± 0.12	1.09 ± 0.11	**0.010**
All carp & catfish	0.04 ± 0.03	0.07 ± 0.03	0.119
Total yield	8.16 ± 0.64	8.00 ± 0.51	0.902

Note: Tilapia size grades: tilapia premium (over 500 g), tilapia super (300–500 g), tilapia grade 1 (200–300 g), tilapia grade 2 (125–200 g), tilapia grade 3 (50–125 g).
* P-values indicated in bold are those significant at least at the 0.10-level.

Table 6
Average fish selling price ($/kg) and average sales revenue generated from fish sales ($/ha) for different species (mean ± SE).

Species and grade	Control	BMP	P-value*
Selling price by species:			
Tilapia ($/kg)	1.50 ± 0.03	1.53 ± 0.02	0.758
Mullet ($/kg)	2.89 ± 0.08	3.08 ± 0.06	0.265
Other fish ($/kg)	1.25 ± 0.01	1.26 ± 0.01	1.000
Weighted price ($/kg)	1.66 ± 0.04	1.79 ± 0.04	**0.025**
Sales revenue by species:			
Tilapia ($/ha)	11,136 ± 1016	10,451 ± 803	0.632
Mullet ($ha)	2047 ± 352	3513 ± 401	**0.004**
Other fish ($/ha)	47 ± 45	94 ± 38	0.121
Total sales revenue ($/ha)	13,230 ± 972	14,058 ± 066	0.508

* P-values indicated in bold are those significant at least at the 0.10-level.

were not significantly different between the two groups, average variable costs were lower for BMP farms than control farms which resulted in significantly lower average total costs (9509 $/ha for BMP farms compared to 10,702 for control farms). This resulted in significantly higher operating profits and average net profits for BMP farms compared to control farms equivalent to return on total sales of 32% for BMP farms compared to only 19% for control farms.

As a form of sensitivity analysis, Table 10 examines the fish selling prices ($/kg) that would have to be set and yields (t/ha) that would have to be achieved to cover average operating costs and average total costs for the two farmer groups. The results show that the breakeven prices to cover variable costs were lower for BMP farms than for control farms but not to cover for total costs. The break-even yields (t/ha) required to cover both operating costs and total costs for control farms were significantly higher than those for BMP trained fish farms.

4. Discussion

The results show that BMP training by farmer trainers had a positive impact on the profitability, but not the productivity of Egyptian fish farms. Through more efficient feed management, the BMP-trained fish farmers were able to reduce their feed costs and achieve better food conversion ratios than their un-trained colleagues. This resulted in average net profits of $4550/ha on BMP farms, compared to only $2527/ha for control fish farms. At an average farm size of 7.5 ha, this means that BMP trained fish farmers were making an average of over $15,000 additional profits compared to control fish farmers.

For many of the fish farmers this was the first time that they had received any technical support or training. The BMP training program needs to be revised and streamlined to take into account the uptake rate and impacts of the individual training modules. More emphasis needs to be placed on critical aspects of the training to further safeguard profitability while also securing the sustainability of the sector through more efficient use of resources and encouraging improved post-harvest handling practices to ensuring product safety for consumers.

Table 7
Average variable costs for control and BMP trained fish farms (mean $/ha ± SE).

Cost components	Control	%	BMP	%	P-value*
Feed	8023 ± 547	79.2	6709 ± 481	75.4	**0.029**
Seed	792 ± 121	7.8	857 ± 63	9.6	0.490
Labor	778 ± 74	7.7	730 ± 64	8.2	0.514
Fuel and electricity	292 ± 31	2.9	261 ± 50	2.9	**0.097**
Fertilizers	101 ± 43	1.0	141.5 ± 22	1.6	**0.000**
Sales commission	65 ± 30	0.6	107 ± 29	1.2	**0.063**
Vet treatment	42 ± 21	0.4	31 ± 8	0.4	0.791
Transportation	28 ± 7	0.3	36 ± 7	0.4	0.983
Ice	3.8 ± 1.8	0.0	9.4 ± 2.5	0.1	**0.036**
Other	8.3 ± 4.5	0.1	10.6 ± 5.3	0.1	0.839
Total Variable Costs	10,133 ± 629	100	8892 ± 543	100	**0.088**

* P-values indicated in bold are those significant at least at the 0.10-level.

Table 8
Average fixed costs for control and BMP fish farms (mean $/ha ± SE).

Cost components	Control	%	BMP	%	P-value*
Land rent	261 ± 65	46	313 ± 64	51	0.869
Repairs and maintenance	155 ± 28	27	188 ± 35	31	0.702
Depreciation	132 ± 27	23	81 ± 8.6	13	0.241
Government charges/fines	21.2 ± 7.3	4	32.9 ± 8.6	5	0.895
Financial charges	0.0	0	0.4 ± 0.4	0	0.149
Total Fixed Costs	569 ± 69.5	100	616 ± 71	100	0.817

* P-values indicated in bold are those significant at least at the 0.10-level.

Although over 2400 fish farmers and fish farm managers completed the BMP training, they represent around 1800 fish farms as some farms provided more than one trainee. Also the impact assessment survey only included the 70% of farms classified as high adopters in the adoption survey which means that we can be certain about incremental profits on 1260 fish farms. Nevertheless, BMP training by the IEIDEAS project can claim to have resulted in $18.9 million additional profits, or added value, for the sector in 2014 alone. This compares favourably with the overall costs to the donor of $4.65 million over 4 years. It should also be taken into account that for many BMP fish farms, 2014 was their first year to apply new management practices. As they become more confident with the new practices, they should be able to generate greater incremental profits.

There is a strong rationale for extension of the BMP training to more fish farmers in Egypt. This intervention only covered around one-third of the farms in the main aquaculture production zones. Renewed donor support means that at least 4000 more farms will be covered in a follow-up intervention, with greater involvement of the aquaculture producer organizations. Meanwhile, now that they have basic technical skills, BMP trainees will be encouraged to continue meeting together and experimenting in local 'farmer field-school' groups to share their knowledge and benefit from further support from BMP trainers and other extension agents (Pant et al., 2014). Other extension approaches should also be considered, including the use of mass media, social media and the private sector to convey key messages to fish farmers (Ariyo et al. 2013; Thompson et al., 2005).

It appears that the main factor contributing to improved profitability on BMP farms was efficient feed management. This will also have had positive impacts on the environmental performance of the BMP fish farms compared to control farms through reduced greenhouse gas emissions and nutrient discharges to adjacent ecosystems (Henriksson et al., 2015).

Egypt is often viewed by other African countries as an aquaculture success story. Over the period 2000 to 2012, Egyptian aquaculture production tripled to over 1 million t/yr which contributed to direct increases in per capita fish consumption from 14.6 kg to 20.6 kg over the same period (GAFRD, 2014). Egyptian farmed fish is providing much-needed food security, dietary diversity and nutrition for a population that suffers from a series of challenges including childhood stunting and obesity (World Food Programme, 2013). Meanwhile, recent projections for fish consumption in Sub-Saharan Africa suggest that it is likely to decline at an annual rate of 1% during the period 2010 to 2030, falling

Table 9
Financial performance of control and BMP trained fish farms (mean ± SE).

Performance indicators	Control	BMP	P-value*
Average revenue ($/ha)	13,230 ± 972	14,058 ± 966	0.508
Average variable costs ($/ha)	10,133 ± 629	8892 ± 543	**0.088**
Average fixed costs ($/ha)	569 ± 69.5	616 ± 71	0.817
Average total costs ($/ha)	10,702 ± 641	9509 ± 573	**0.085**
Average operating profit ($/ha)	3096 ± 593	5166 ± 581	**0.007**
Operating profit (% of sales)	(23%)	(36%)	–
Average net profits ($/ha)	2527 ± 588	4550 ± 565	**0.008**
Net profit (% of sales)	(19%)	(32%)	–

* P-values indicated in bold are those significant at least at the 0.10-level.

Table 10
Break-even analysis for control and BMP trained fish farms ($/kg and t/ha).

Break even categories	Control	BMP	P-value*
Break-even price to cover operating costs ($/kg)	1.34 ± 0.06	1.19 ± 0.04	**0.082**
Break-even price to cover total costs ($/kg)	1.42 ± 0.06	1.28 ± 0.04	0.112
Break-even yield to cover operating costs (t/ha)	6.30 ± 0.41	5.15 ± 0.33	**0.012**
Break-even yield to cover total costs (t/ha)	6.65 ± 0.42	5.51 ± 0.34	**0.016**

The values are expressed as mean ± SE.
* P-values indicated in bold are those significant at least at the 0.10-level.

to 5.6 kg (from 7.1 kg in 2006) because of limited production increases and rapid population growth (World Bank, 2013). A rapid expansion of aquaculture production is urgently needed to fill the growing gap between supply and demand for fish across the continent (Beveridge et al., 2013).

The current study indicates that although Egyptian aquaculture is mature, at least compared to other countries in Africa, there is still much that can be done to improve the efficiency and profitability of Egyptian fish farms. Simple messages such as improving feeding practices can have a significant impact on farm profitability, transforming aquaculture businesses from just surviving into thriving, profitable enterprises. The approaches used in this study, including the use of private-sector fish farmers as extension agents and the development of locally adapted best management practices should be applied elsewhere in Africa to help accelerate aquaculture development across the continent.

Acknowledgements

This work was supported by the Swiss Agency for Development and Cooperation [project number 7F08042] through the 'Improving Employment and Incomes through the Development of Egypt's Aquaculture Sector' (IEIDEAS) project. Additional support was provided by the CGIAR Research Program on Livestock and Fish, which in turn is supported by the CGIAR Fund Donors. The authors gratefully acknowledge the fish farmers who responded to questionnaires and willingly provided information, the field team who collected these data, and the farmer trainers who facilitated the training sessions.

References

Ansah, Y.B., Frimpong, E.A., 2015. Impact of the adoption of BMPs on social welfare: a case study of commercial floating feeds for pond culture of tilapia in Ghana. Cogent Food & Agriculture (2015) 1, 1048579 (http://dx.doi.org/10.1080/23311932.2015.1048579).
Ansah, Y.B., Frimpong, E.A., Amisah, S., 2013. Characterisation of potential aquaculture pond effluents, and physico-chemical and microbial assessment of effluent-receiving waters in central Ghana. Afr. J. Aquat. Sci. 38, 1–8.
Ariyo, O.C., Ariyo, M.O., Okelola, O.E., Aasa, O.S., Awotide, O.G., Aaron, A.J., Oni, O.B., 2013. Assessment of the role of mass media in the dissemination of agricultural technologies among farmers in Kaduna North Local Government Area of Kaduna State, Nigeria. J. Biol. Agric. Healthc. 3, 19–28.
Asmah, R., 2008. Development Potential and Financial Viability of Fish Farming in Ghana. Ph.D Thesis. University of Stirling.
Beveridge, M.C.M., Thilsted, S.H., Phillips, M.J., Metian, M., Troell, M., Hall, S.J., 2013. Meeting the food and nutrition needs of the poor: the role of fish and the opportunities and challenges emerging from the rise of aquaculture. J. Fish Biol. 83, 1067–1084.
Boyd, C.E., Queiroz, J., McNevin, A., 2013. Perspectives on the responsible aquaculture movement. J. World Aquacult. Soc. 14–21 December 2013.
El-Gayar, O., 2003. Aquaculture in Egypt and issues for sustainable development. Aquac. Econ. Manag. 7 (12), 137–154.
El-Naggar, G.O., Hassanen, G.D., Abdou, M.R., El-Dakar, A.Y., Nasr-Allah, A.M., 2010. Effects of using different fertilization strategies supplemented with feed on fish yield, pond water quality and economic return. Abbassa Inter. J. for Aqua 333–351.
El-Sayed, A.F.M., Dickson, M.W., El-Naggar, G.O., 2015. Value chain analysis of the aquaculture feed sector in Egypt. Aquaculture 437, 92–101.
Engle, C., Valderrama, D., 2004. Economic effects of implementing selected components of best management practices (BMPs) for semi-intensive shrimp farms in Honduras. Aquac. Econ. Manag. 8, 157–177.
Engle, C.R., Pomerleau, S., Fornshell, G., Hinshaw, J.M., Sloan, D., Thompson, S., 2005. The economic impact of proposed effluent treatment options for production of trout *Oncorhynchus mykiss* in flow-through systems. Aquac. Eng. 32, 303–323.
Field, A.P., 2009. Discovering Statistics Using SPSS (and Sex and Drugs and Rock' n' roll). 3rd ed. Sage, London.
Frimpong, E., Ansah, Y., Amisah, S., Adjei-Boateng, D., Agbo, N., Egna, H., 2014. Effects of two environmental best management practices on pond water and effluent quality and growth of Nile tilapia, *Oreochromis niloticus*. Sustainability 6, 652–675 (http://dx.doi.org/10.3390/su6020652).
GAFRD, 2016. General Authority For Fishery Resources Development. Fish Statistics Yearbook 2014. Ministry of Agriculture and Land Reclamation, Egypt.
GAFRD, 2014. General Authority For Fishery Resources Development. Fish Statistics Yearbook 2013. Ministry of Agriculture and Land Reclamation, Egypt.
Henriksson, P.J.G., Rico, A., Zhang, W., Nahid, S.A.A., Newton, R., Phan, L.T., Zhang, Z., Jaithiang, J., Dao, H.M., Phu, T.M., Little, D.C., Murray, F.J., Satapornvanit, K., Liu, L., Liu, Q., Haque, M.M., Kruijssen, F., de Snoo, G.R., Heijungs, R., Guinée, J.B., 2015. Comparison of Asian aquaculture products by use of statistically supported life cycle assessment. Environ. Sci. Technol. 49, 14176–14183. http://dx.doi.org/10.1021/acs.est.5b04634.
Jolly, C.M., Clonts, H.A., 1993. Economics of Aquaculture. Food Products Press, New York.
Klinger, D., Naylor, R., 2012. Searching for solutions in aquaculture: charting a sustainable course. Annu. Rev. Environ. Resour. 37, 247–276 (http://dx.doi.org/10.1146/annurev-environ-021111-161531).
Macfadyen, G., Nasr-Allah, A.M., Kenawy, D.A.R., Ahmed, M.F.M., Hebicha, H.A., Diab, A., Hussein, S.M., Abou-zeid, R.M., El-Naggar, G., 2012. Value-Chain Analysis – an assessment methodology to estimate Egyptian aquaculture sector performance, and to identify critical issues and actions for improvements in sector performance. Aquaculture 362–363, 18–27.
Nasr-Allah, A., Macfadyen, G., Dickson, M., Al–Kenawy, D., Fathi, M., El-Naggar, G., 2012. Value chain analysis of the Egyptian aquaculture sector. Proceedings of IIFET Conference in Dar Al-Salam, Tanzania from 16 to 20 July 2012.
Nasr-Allah, A., Dickson, M.W., Kenawy, D.A., Ahmed, M.F.M., El-Naggar, G.O., 2014. Technical characteristics and economic performance of commercial tilapia hatcheries applying different management systems in Egypt. Aquaculture 426–427, 220–230.
Pant, J., Barman, B.K., Murshed-E-Jahan, K., Belton, B., Beveridge, M., 2014. Can aquaculture benefit the extreme poor? A case study of landless and socially marginalized Adivasi (ethnic) communities in Bangladesh. Aquaculture 418–419, 1–10.
Poot-López, G.R., Hernández, J.M., Gasca-Leyva, E., 2014. Analysis of ration size in Nile tilapia production: Economics and environmental implications. Aquaculture 420–421, 198–205.
Thompson, P.M., Sultana, P., Firoz Khan, A.K.M., 2005. Aquaculture extension impacts in Bangladesh: a case study from Kapasia, Gazipur. WorldFish Center Technical Report 63, 75.
World Bank, 2013. Fish to 2030: prospects for fisheries and aquaculture. Agriculture and Environmental Services Discussion Paper; no. **3**. World Bank Group, Washington DC http://documents.worldbank.org/curated/en/2013/12/18882045/fish-2030-prospects-fisheries-aquaculture.
World Food Programme, 2013. The Status of Poverty and Food Security in Egypt: Analysis and Policy Recommendations. WFP, Cairo Accessed at: http://documents.wfp.org/stellent/groups/public/documents/ena/wfp257467.pdf.