Impact and cost-effectiveness of women's training in home gardening and nutrition in Bangladesh

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ABSTRACT
This study quantifies the impact and cost-effectiveness of training poor rural women in Bangladesh in home gardening and nutrition. We use baseline and follow-up data for 646 intervention and control households and apply a difference-in-difference estimator. We find that the intervention significantly (p < 0.01) increased vegetable production (+16.5 g/person/day), vegetable consumption and the micronutrient supply from the garden. Using the disability-adjusted life years (DALYs) approach, we show that the intervention can be considered cost-effective in abating iron, vitamin A and zinc deficiencies. Home garden interventions can therefore make an effective contribution to addressing micronutrient undernutrition.

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1. Introduction

There is growing interest in the potential of home-based food production to address micronutrient undernutrition in developing countries (e.g. Keatinge et al. 2012; Olney et al. 2015; Weinberger 2013). Several recent reviews have recognised that interventions in home-based food production, and home gardens in particular, can be more effective in reaching nutritional outcomes than interventions in cash crop production (Berti, Krasevec, and FitzGerald 2004; Galhena, Freed, and Maredia 2013; Girard et al. 2012; Masset et al. 2012; Ruel and Alderman 2013).

The impact pathway of home gardening interventions is straightforward. Poor women are trained how to grow crops rich in micronutrients on small plots of land near their homestead, and how to do this year-round. Concurrently they are trained about the importance of nutrition, which raises their demand for these crops, and cooking methods that best preserve the micronutrient content. After the training, women are assumed to establish a home garden (or improve an existing one) and address production constraints such as water supplies, labour time, pest control and basic input supplies. This leads to increased production of micronutrient-rich food, while households are assumed to consume most of it rather than sell it. However compelling the basic concept, the evidence base for the link between home garden interventions and nutrition outcomes is small.

A recent review of home gardening by the UK Department of International Development found 15 papers in English in peer-reviewed journals that had done an impact evaluation in low- or middle-income countries (DFID 2014). Only seven reported a link between home gardening and micronutrient status, while 10 showed a link between home gardening and increased production and consumption of micronutrient-rich foods. The review mentioned that no cost-effectiveness study has been performed on home garden interventions, and concluded that...
there is a need for better-quality impact studies because most previous studies were observational rather than experimental or quasi-experimental.

Of the 15 impact studies, three were conducted in Bangladesh. Bangladesh is particularly suitable for this type of intervention because of the intense land scarcity and high rates of micronutrient undernutrition. In Bangladesh, home garden interventions have been promoted by international and local non-governmental organisations (NGOs) since the early 1990s and the government has officially endorsed the concept. Hellen Keller International has trained nearly 900,000 households in home gardening (Iannotti, Cunningham, and Ruel 2009). Various other aspects of home gardening in Bangladesh have been well documented, such as the contribution to biodiversity conservation (e.g. Bardhan et al. 2012), gender equality (e.g. Hillenbrand 2010; Patalagsa et al. 2015) and socio-economic functions (e.g. Ali 2005).

Bushamuka et al. (2005) quantified the impact of the homestead food production programme of Hellen Keller International using cross-sectional data for 2,160 households. They compared households who received gardening support with a control group of households who did not get support. The study potentially suffers from selection bias as there were clear differences between control and intervention households and these were not controlled for in the analysis. The study found a threefold increase in vegetable production (from 46 to 135 kg) and a twofold increase in household vegetable consumption (from 38 to 85 kg) over a three-month period. Furthermore, the study found that more than 3 years after the intervention, these positive effects had been sustained, although the effect on consumption had become less.

Kumar and Quisumbing (2011) evaluated the impact of an intervention supplying women with improved varieties for small-scale vegetable production in Saturia district (near Dhaka). Using data from 1996 to 2006 for 313 control and treatment households, they found sustained improvements in the nutritional status of women and children for early adopters, but negligible monetary gains. However, this intervention is different from a typical home garden intervention, as it did not include training in nutrition and did not focus on micronutrient-rich vegetables.

More recently, Schreinemachers et al. (2015) evaluated a home garden programme, including training in gardening and nutrition, targeted at poor rural women in two districts of southwestern Bangladesh. They found no evidence of selection bias in their sample, and therefore carried out a straightforward comparison between the 479 control and 103 intervention households. Results showed that the intervention households had an 86 per cent higher per capita production of mostly leafy vegetables (37 kg per year as compared to 20 kg for the control). The diversity of production and frequency of harvesting were also higher. In terms of nutrient yields, they found a 171 per cent greater supply of plant proteins, 284 per cent for iron, 189 per cent for vitamin A and 290 per cent for vitamin C.

The present study partially uses the same data as Schreinemachers et al. (2015), but uses two years of observations, applies a difference-in-difference method to control for selection bias and expands it from two to four districts in southwestern Bangladesh. The study tests the hypotheses whether training poor rural women in home gardening and nutrition increases home-based vegetable production, micronutrient yields and the quantity and diversity of vegetable consumption one year after the training. The study is also the first to carry out a cost-effectiveness analysis of a home garden intervention.

2. Material and methods

2.1. Intervention and targeting

Fruit and vegetables are an important component of a healthy diet. Globally, low fruit and vegetable intake ranks among the top 10 risk factors contributing to mortality (WHO 2003). In Bangladesh, the consumption of fruit and vegetables has slowly increased in the last decade, but the average per capita daily consumption of 212 g is below the level of 400 g as recommended by
Food and Agriculture Organization of the United Nations (FAO) and World Health Organization (WHO) (Nahar et al. 2013). Home gardening by poor rural households has been identified as an effective approach to improve this.

Since the early 1990s, the World Vegetable Center has implemented home gardens in Bangladesh (for a description of the approach, see World Vegetable Center 2016). Since 2011, the Center has worked with two local NGOs to implement home gardens as part of a United States Agency for International Development (USAID)-funded project. BRAC, a large international NGO based in Bangladesh, is handling the implementation in Jessore and Barisal districts, while Proshika is leading the effort in Potuakhali and Faridpur districts. Between 2012 and 2015, over 10,000 women received the training.

Several criteria were defined for women to be eligible for receiving project support: First, the household must own some land but not more than one acre (0.4 ha). This was to ensure that the intervention targets smallholder households. It admittedly excludes poor landless households; for them, a different garden design using pots and crop species suitable for growing in pots is more suitable. Second, households with at least one child below the age of five were given priority. Third, the women must have some experience in growing vegetables; however, they should not be recipients of any similar intervention in the past. Last, participation was voluntary and women should therefore have an interest in the project.

The intervention focused on introducing improved (open pollinated) nutrient-rich vegetable varieties suitable for growing in a home garden and for which seed was locally available. These vegetables included stem amaranth/red amaranth (Amaranthus spp.), bitter gourd (Momordica charantia), Indian spinach (Basella alba), okra (Abelmoschus esculentus), sweet potato (Ipomoea batatas) for vines and young shoots, water spinach (Ipomoea aquatica) and yard-long bean (Vigna unguiculata subsp. sesquipedalis). Although not rich in nutrients, cucumber (Cucumis spp.) was added because of local preferences. The women could also include other plants in their garden.

The women were given a one-day intensive training class that focused on nutrition and garden establishment. Training sessions took place at a local training centre during the second quarter of the year. There were instructors who managed the training, with about 10–15 women participants per session. Overall, the training was divided into two parts: classroom teaching and hands-on practice in a demonstration garden. Among the many things taught during the training, women learned about the importance of nutrition in preventing diseases, the body functions of various nutrients, nutritional value of commonly consumed vegetables, and the available nutrients from different colours of vegetables. It also taught women how to preserve the nutritional content of vegetables during cooking.

For the technical part of the training, women were taught about site selection, site and land preparation, garden layout and design, raised planting bed preparation, proper fencing, seasonal vegetable selection, sowing practices, fertiliser application, irrigation and drainage, weeding, and insect and disease management without pesticides. Although home gardens are common in Bangladesh, this intervention’s improved home garden design is different from usual practices as it makes use of raised planting beds, taught the women how to better plan their gardens, constructed fences with synthetic nets and locally available materials to keep out farm animals, and taught the importance of using quality seeds. After the training, participants were encouraged to share the knowledge they acquired with their neighbours.

Participants of the training were given a follow-up visit 7–14 days after the training. The training officers provided assistance in setting up the garden, and they were readily available to answer questions. Women received seed packs for growing the seven vegetables listed above and vines for planting sweet potato after the officer had observed that the planting beds were near completion. The training officers visited the home gardens on an almost-weekly basis for the first six months of the training. For the second six months after the training, the visiting frequency was reduced to a monthly basis.
2.2. Evaluation approach

The study used a quasi-experimental design comparing pre- and post-intervention data for a group of intervention households that received training and support in home gardening, and a group of control households that did not receive training or support. Selection bias was minimised by applying the same eligibility criteria on the control group as what was used for selecting the intervention group. Self-selection bias did not occur because the project was able to control who did and did not receive the intervention. Hence, households could not ask to receive the intervention from the project. We tested for significant differences in means in household characteristics and outcome variables at the baseline.

The study applied a difference-in-difference estimator. It compares the average change in outcome indicators over time for the intervention and control group. The following model was estimated using Ordinary Least Squares:

\[
\text{Outcome indicator} = \alpha + \beta \text{(Treatment)} + \gamma \text{(Period)} + \delta \text{(Treatment × Period)}
\]

where Treatment is a dummy variable separating the intervention group from the control group and Period is a dummy variable separating the baseline data from the follow-up data. The parameter \(\delta\) quantified the impact of the intervention, which is the average treatment effect.

The method effectively eliminates the effect of selection bias, but makes a key assumption that the average change in the control group represents the counterfactual change in the intervention group in the absence of the project (Gertler et al. 2011, 96). This ‘parallel paths’ assumption cannot be tested with our data, but we have good reasons to believe that the assumption holds. First, the control and intervention villages come from the same upazillas (subdistricts) and unions (village clusters) and are therefore exposed to the same drivers of change such as policies, markets and weather. Second, a relatively large number of 46 villages were included in the sample, which mediates the potential effect if some villages received benefits from another project. Third, the two surveys were made only one year apart, which increases the likelihood that the control and intervention households are subject to the same drivers of change other than the project.

There is potential bias from spillover effects of the intervention on the control group because the trained women had been encouraged to share their new knowledge with their neighbours. If such spillover did occur, then the evaluation is likely to underestimate the true impact of the intervention. This source of bias was minimised by selecting control and intervention households from different villages. The short period between baseline and follow-up data further reduced the likelihood of spillover effects.

2.3. Outcome indicators

This study used a range of outcome indicators to quantify the effect of home vegetable gardens on households’ vegetable production and consumption.

Vegetable production was expressed in kilograms per household member per year. Production data were collected using a 12-month recall period divided into summer (kharif) and winter (rabi). Respondents were asked which vegetables they grew, how many times they harvested in each season and the average amount they harvested each time. Harvested quantities of 32 vegetables, which include those in the home garden kits as well as those chosen by the women in the households, were divided into five groups: cucurbits and eggplants, roots and tubers, beans and pulses, leafy vegetables and other vegetables (e.g. okra, tomato). The survey recorded how much of the production was consumed within the household, shared with others or sold.

Nutrient yields were calculated from the vegetable production data using food composition tables taken from the United States Department of Agriculture (USDA 2015) for 24 vegetables, and from World Vegetable Center (2014) for four traditional vegetables not included in the USDA database (snake gourd, country bean, stem amaranth and red amaranth).
specifically looked into the supply of plant proteins, calcium, iron, folate, zinc, vitamin A and vitamin C. Previous research showed gaps in the supply of these nutrients in Bangladesh (Arsenault, Hijmans, and Brown 2015; Meenakshi et al. 2010; Nahar et al. 2013). Nutrient conversion factors for the category ‘other vegetables’ and four vegetables for which factors were unavailable (bottle gourd leaf, radish leaf, pointed gourd and aroid leaf) were replaced with the quantity-weighted average for all other vegetables in the same group. Plant-based precursors to vitamin A (pro-vitamin A, beta-carotene) were expressed in International Units (IU) following USDA (2015).

Quantity of vegetables consumed, expressed in grams per capita per day, was calculated using a 24-hour recall method. Data were available from the follow-up survey, but not from the baseline survey. Respondents were asked for the amount of raw vegetables used as ingredients for preparing breakfast, lunch and dinner for the household. Respondents were also asked if there had been any leftovers at each meal, the amount of which was deducted from the estimated quantity. Quantities were recorded for 32 different kinds of vegetables. The source of the vegetables (home garden, commercial field, bought, received for free and others) was also recorded. In addition, we calculated the number of different vegetables consumed as an indicator of dietary diversity.

Intermediary outcome variables, which help articulate the impact pathway of the intervention, include the time allocation of women and men to working in the home garden, the changes made to the home garden after the training, inputs used in the home garden and challenges encountered in doing home gardening.

2.4. Cost-effectiveness analysis

The intervention was part of a three-year project funded by USAID. Costs from October 2011 to September 2014 were calculated from project financial reports, project work plans and information obtained from key persons involved in the project. The costs of implementation were straightforward to calculate because subcontracts had been agreed upon with implementing agencies. Yet, costs such as office rent and project management were more difficult to quantify, as the home garden training was only one component of the larger project. The project managers estimated that they had spent 5 per cent of their time on the home garden component and that the field staff had spent 15 per cent on it. The same figures were used to allocate a proportion of the project’s operational and travel expenses to the home garden component. We added organisational overhead and the cost of the impact evaluation to the total costs.

The opportunity cost of women’s time was approximated as the product of days spent on the training and home gardening and half the average minimum daily wage in rural Bangladesh. This low wage rate was used because within the local cultural context it is considered inappropriate for women to do off-farm work. We tested the sensitivity of our results to alternative assumptions about the valuation of women’s time. The opportunity cost of women is a recurring annual cost, while all other costs are one-time costs. The opportunity cost of the land was assumed zero because most home gardens were established on compound land and because there was no significant expansion of the garden area as a result of the intervention. All costs were converted into 2014 US dollar values. The total cost was divided by the number of trained households to estimate the cost per beneficiary household.

The disability-adjusted life years (DALYs) method is widely used to measure health outcomes, and it is an established metric to quantify the cost of micronutrient undernutrition (Murray 1994; Murray and Acharya 1997). It provides an annual measure of the disease burden, including temporary illness, permanent conditions and mortality. DALYs lost are the sum of years of life lost and years lived with disability. On the other hand, DALYs saved reflect the reduced burden of disease as a result of a public health intervention and are a measure of the benefit of training women in home gardening and nutrition. The method has been widely applied to estimate the
cost-effectiveness of agricultural interventions in terms of health outcomes (e.g. Meenakshi et al. 2010; Stein et al. 2007; Stein, Sachdev, and Qaim 2008).

To estimate DALYs saved, the micronutrient intake gap before and after the intervention was first calculated. The intake gap before the intervention is the ratio of current micronutrient intake and recommended nutrient intake (RNI), both based on secondary data published in Nahar et al. (2013). We then added the micronutrient supply from the home garden to the current micronutrient intake to estimate the intake gap after the intervention. From these two ratios, the percentage reduction in micronutrient intake gap was calculated. We then assumed that a 1 per cent reduction in the intake gap of a particular micronutrient would translate into a 1 per cent reduction in the burden of disease of that micronutrient. From this, we then calculated the DALYs saved.

Some previous studies have argued that the link between nutrient intake and health outcomes might not be proportional as the effect of a 1 per cent reduction in the nutrient intake gap might be greater at lower levels of intake (Zimmermann and Qaim 2004). Yet we here assume it to be proportional for lack of a generally accepted functional form between nutrient intake and DALYs. Our calculations might therefore underestimate the true impact of the intervention where the current nutrient intake gap is large.

The cost per DALY saved provides an indicator of cost-effectiveness that can be compared to other public health interventions. The WHO suggested dividing the cost per DALY saved by the national per capita income level of a country, which is a proxy for the value of one year lost due to illness or mortality (Asare-Marfo et al. 2014). A health intervention can be considered ‘very cost-effective’ if this ratio is less than unity and ‘cost-effective’ if it is below 3 (ibid.).

2.5. Data collection

Data were collected from four districts in southwestern Bangladesh targeted by the project in 2013: Barisal, Faridpur, Jessore and Potuakhali (Table 1). To represent the intervention area, 12 upazillas (subdistricts) were purposively selected from the four districts. Unions, the smallest rural administrative unit that typically consists of nine villages, were randomly selected from each upazilla’s intervention area, while unions in the control group were purposively selected to have similar characteristics. The sample villages were selected from a list of all villages in the selected unions. From each village, 10–15 households from the list of women who participated in the training were randomly selected as part of the sample. Only women were interviewed, with all agreeing to participate.

Baseline and follow-up data were collected in April–May during the end of the winter (rabi) season when home gardens are usually unproductive because of drought. It was important to assess whether the intervention could help increase the vegetable supply during this season. Baseline data were collected in 2013 from 425 women in the intervention group and from 252 women in the control group, while follow-up data were conducted in 2014 and included 408 and 238 women in each group, respectively. All women in the intervention group were found to have received the intervention, while all women in the control group were found not to have received the intervention. The 5 per cent sample attrition was explained by women being absent from their home during the visit. We found no significant difference in mean household characteristics between this group and the other households in the baseline. The same structured questionnaire

| Table 1. Sample selection. |
|---------------------------|
| Level                     | Intervention | Control | Unique sample units |
| Districts                 | 4            | 4        | 4                   |
| Upazillas (subdistricts)  | 9            | 8        | 12                  |
| Unions (clusters of villages) | 17         | 9        | 26                  |
| Villages                  | 28           | 18       | 46                  |
| Households (primary sampling units) | 408      | 238       | 646                 |
was used for the baseline and follow-up survey, but the follow-up survey additionally included a 24-hour recall of vegetable consumption.

3. Results

There were no significant differences in basic household characteristics between the control and intervention groups either before or after the intervention (Table 2). This suggests the absence of selection bias as far as observable household characteristics are concerned. All women in the intervention group adopted a home garden after having received the training. It is notable that we did not find an increase in the average area dedicated to the home garden for the intervention group between the baseline and follow-up survey. Therefore, any increases in vegetable production can be attributed to an intensification of the existing home garden area.

3.1 Home garden management

A comparison of data between the control and intervention groups (Table 3) shows that women who received the training made a large number of changes to how they managed their home garden. Most of these changes were significantly different \( (p < 0.01) \) from the group of control households, which also made several improvements but to a lesser degree. Common changes made after the training included the introduction of new crops, the use of raised planting beds, use of quality seed, crop rotations, relay cropping and new fencing.

Nearly all women, trained and nontrained, encountered some problems with their home gardens. The most frequent problems included difficulty in controlling pests and diseases, plants destroyed by livestock and expensive seed (Table 4). Four of the major problems were reported by a significantly \( (p < 0.01) \) smaller proportion of women in the intervention group. Yet it must be kept in mind that a small packet of quality seed was supplied to the women after the training. However, the proportion of women who felt that there was not enough water was higher in the intervention group, which is understandable, as water only became a constraint when they tried year-round vegetable production and also because more productive crops require more water. Lack of time to manage the home gardens was mentioned as a constraint by 1 per cent of the

Table 2. Household characteristics of trained and nontrained households (average per household), standard deviations in italics.

|                     | Baseline       | p-value<sup>a</sup> | Follow-up       | p-value<sup>a</sup> |
|---------------------|----------------|---------------------|-----------------|---------------------|
|                     | Control (n = 238) | Intervention (n = 408) |                     | Control (n = 238) | Intervention (n = 408) |
| Household size (persons) | 4.97             | 4.81                | 0.203           | 5.03             | 4.89                | 0.260 |
|                     | 1.57             | 1.51                | NS              | 1.65             | 1.56                | NS |
| Males               | 2.49             | 2.36                | 0.140           | 2.50             | 2.38                | 0.214 |
|                     | 1.22             | 1.07                | NS              | 1.31             | 1.09                | NS |
| Females             | 2.48             | 2.46                | 0.807           | 2.53             | 2.50                | 0.779 |
|                     | 1.15             | 1.16                | NS              | 1.13             | 1.20                | NS |
| Adults (≥18 years)  | 2.97             | 2.82                | 0.110           | 3.06             | 2.91                | 0.122 |
|                     | 1.20             | 1.14                | NS              | 1.29             | 1.20                | NS |
| Children 5–17 years | 1.33             | 1.37                | 0.662           | 1.45             | 1.51                | 0.421 |
|                     | 1.11             | 1.01                | NS              | 1.09             | 1.04                | NS |
| Children under 5 years | 0.67            | 0.63                | 0.362           | 0.53             | 0.47                | 0.229 |
|                     | 0.61             | 0.60                | NS              | 0.61             | 0.60                | NS |
| Cultivated land owned (ha) | 0.16             | 0.14                | 0.222           | 0.16             | 0.14                | 0.233 |
|                     | 0.16             | 0.16                | NS              | 0.16             | 0.16                | NS |
| Cultivated land rented (ha) | 0.10             | 0.08                | 0.236           | 0.11             | 0.10                | 0.418 |
|                     | 0.13             | 0.17                | NS              | 0.15             | 0.18                | NS |
| Home garden land (m²) | 43.3             | 42.8                | 0.702           | 44.2             | 43.7                | 0.726 |
|                     | 20.5             | 15.2                | NS              | 22.4             | 15.6                | NS |

<sup>a</sup> Two-sample t-test. Significance levels: *** \( p < 0.01 \), ** \( p < 0.05 \), * \( p < 0.10 \), NS = Not significant \( p \geq 0.10 \).
trained women. Further analysis showed that the average trained women spent 7 min per day on the home garden, which was an average increase of 2.5 min ($p < 0.01$) as a result of the intervention. Men spent on average 3–4 min/day on the home garden, mostly on preparing the land, and this was not affected by the intervention ($p = 0.30$).

### 3.2. Vegetable production

Households that had received the intervention harvested an average quantity of 108.7 kg of vegetables and fruit from their home garden (Table 5). The difference-in-difference estimator suggested a 31.0 kg increase ($p < 0.01$) as a result of the intervention. This additional amount translates into a daily per capita quantity of vegetables of 16.5 g.

Increased production of nutrient-dense leafy vegetables (mostly amaranth, Indian spinach and kangkong) accounted for half the increase in vegetable supply, while the quantity of cucurbits and eggplants significantly decreased. Cucurbits, mostly including watery gourds such as bottle gourd, winter melon, sweet gourd and luffa, made up about half the garden harvest before the intervention, but only one-fifth for the trained households after the intervention. The training thus shifted garden production towards nutrient-dense vegetables. This shift towards leafy vegetables, which are lighter and more nutritious, makes the observed increase in weight more noteworthy.

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Table 3. Home garden management methods used by control and intervention households in the post-intervention survey, in proportion to respondents doing gardening, 2014.

| Changes made                        | Control ($n = 236$) | Intervention ($n = 408$) | $p$-value$^a$ |
|-------------------------------------|---------------------|--------------------------|---------------|
| Improved planting beds              | 0.03                | 0.88                     | 0.000***      |
| Introduced new crops                | 0.15                | 0.86                     | 0.000***      |
| Started using quality seed          | 0.12                | 0.84                     | 0.000***      |
| Used relay cropping                 | 0.30                | 0.83                     | 0.000***      |
| Introduced crop rotations           | 0.12                | 0.53                     | 0.000***      |
| Strong fences                       | 0.36                | 0.51                     | 0.000***      |
| Improved pit/heap system$^b$        | 0.04                | 0.42                     | 0.000***      |
| Practiced thinning/pruning          | 0.07                | 0.30                     | 0.000***      |
| Organic fertiliser                  | 0.19                | 0.21                     | 0.591         |
| Biopesticides                       | 0.02                | 0.19                     | 0.000***      |
| Inorganic fertiliser                | 0.12                | 0.14                     | 0.604         |
| Chemical pesticides                 | 0.06                | 0.12                     | 0.021***      |
| Mulches                             | 0.00                | 0.02                     | 0.109         |
| Prepared compost                    | 0.01                | 0.01                     | 0.656         |

Table sorted in descending order by intervention group. $^a$Chi-square test. Significance levels: ***$p < 0.01$, **$p < 0.05$, *$p < 0.10$. $^b$For planting tubers.

Table 4. Problems encountered in home gardening, in proportion to respondents doing gardening, 2014.

| Problem                               | Control ($n = 236$) | Intervention ($n = 408$) | $p$-value $^a$ |
|---------------------------------------|---------------------|--------------------------|---------------|
| Pests and diseases                    | 0.64                | 0.45                     | 0.000***      |
| Produce destroyed by animals          | 0.56                | 0.54                     | 0.580         |
| Seed too expensive                    | 0.47                | 0.29                     | 0.000***      |
| Not enough information                | 0.33                | 0.08                     | 0.000***      |
| Lack of quality seed/planting material| 0.27                | 0.07                     | 0.000***      |
| Not enough water                      | 0.20                | 0.35                     | 0.000***      |
| Small seed packs unavailable          | 0.10                | 0.14                     | 0.099         |
| Produce was stolen                    | 0.10                | 0.12                     | 0.333         |
| Area of the garden too small          | 0.08                | 0.06                     | 0.232         |
| Not enough time                       | 0.02                | 0.01                     | 0.377         |

Table sorted in descending order by control group. $^a$Chi-square test. Significance levels: ***$p < 0.01$, **$p < 0.05$, *$p < 0.10$. 

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The trained households consumed most of the home garden produce within the own household (75 per cent), but households in the intervention group also shared some of the increased harvest with others (+5 kg per year). The amount of vegetables sold did not change significantly.

During the training, women had been encouraged to consume the vegetables rather than sell them. This does not mean that there are no monetary gains from the improved home garden, as income saved from not having to buy vegetables could be important, but we did not quantify this in our study. The increase in vegetable production was achieved only during the kharif (summer) season, while the increase in the rabi (winter) season, when vegetable supplies are scarcer, was small and insignificant. We will return to this in the discussion.

The increased garden production is more remarkable when expressed in quantities of nutrients (Table 6). Although the quantity of vegetables increased by only 33 per cent, the supply of iron, folate, zinc and protein increased by 80–95 per cent, the supply of vitamin A and calcium increased by about 135 per cent, and the supply of vitamin C increased by 175 per cent.

### 3.3. Vegetable consumption

The 24-hour recall data on vegetable consumption were only available from the follow-up survey, which prevented us from using a difference-in-difference estimator. Since the results in Tables 2 and 5 show no evidence of selection bias, we simply calculated the difference in means between the control and intervention groups. The results show that the intervention households consumed 254.4 g of vegetables and fruit per capita per day as compared to...
235.1 g for the control group ($p < 0.01$) (Table 7). This suggests an increase of 19.3 g of vegetables and fruit per capita per day, or an 8.2 per cent increase during the *rabi* season. The same data also suggest that the intervention households consumed a greater number of different vegetables.

### 3.4. Cost-effectiveness

The cost for the project to establish a home garden steadily declined from US$178 in 2011–12 to US$47 in 2013–14 as the scale of the project increased (Table 8). The opportunity cost of women’s time spent on the training and gardening was US$13.7. There was no significant increase in input use, but this might have been masked by the free provision of seed in the first year of the project. We therefore added this amount (US$2.9) to subsequent years. Assuming that the impact of the training lasts for 5 years, after which women would need retraining, the annualised cost per home garden is US$23.2, of which 42 per cent is for women’s time spent. The assumed opportunity cost of women’s time thus appears as critical to evaluate the cost-effectiveness of the intervention.

Based on a per capita daily recommended level of 200 g of vegetables, the improved home gardens supplied 33.6 per cent of these needs, of which 8.2 per cent could be attributed to the home garden intervention (Table 9). Data reported in Nahar et al. (2013) show an average daily per capita intake of 167 g of vegetables for Bangladesh as a whole – suggesting an intake gap of 33 g or 16.5 per cent. The intervention can potentially close this gap by 50 per cent, assuming that the additional vegetable supply is consumed, which appears reasonable as we did not find a significant increase in the amount of vegetables sold (Table 5). We note that spoilage is minimal because
women would only harvest from the home garden what they would actually use. The same calculations were made for micronutrients; the figures show the intervention has the potential to close the micronutrient intake gap for calcium, iron and folate by 4–6 per cent and vitamin A by 100 per cent.

According to Nahar et al. (2013), the mean intake of zinc for the Bangladesh population is already above the RNI, which suggests there is no intake gap for zinc. However, the use of population means hides important micronutrient deficiencies affecting particular segments of the population. Ahmed et al. (2012) and Meenakshi et al. (2010) reported substantial zinc deficiencies for Bangladesh and IHME (2015), estimated the cost of zinc deficiency to be 225 thousand DALYs. As the iron intake gap was estimated to be 40 per cent and the vitamin A intake gap to be 32 per cent, we assumed a zinc intake gap of 36 per cent. This should be realistic given that these micronutrients, together with iodine, are widely seen as the four major micronutrient deficiencies in Bangladesh (Ahmed et al. 2012).

| Table 8. Annual cost of the home garden intervention 2011–2014, in constant 2014 US dollars. |
|----------------------------------|----------------|----------------|----------------|----------------|
| Cost item                        | 2011–12        | 2012–13        | 2013–14        | Total          |
| Home gardens established          | 300            | 3,500          | 4,500          | 8,300          |
| Direct costs (×1,000 USD)         | 43.4           | 159.0          | 172.1          | 374.6          |
| – Project planning and organisation | 15.0           | 4.7            | 2.8            | 22.6           |
| – Dhaka project office            | 5.4            | 9.8            | 10.7           | 25.9           |
| – Field coordination in districts | 1.6            | 5.9            | 11.4           | 18.8           |
| – Implementing NGOs               | 21.4           | 118.4          | 139.1          | 278.9          |
| – Impact evaluation               | 0.0            | 20.2           | 8.1            | 28.3           |
| Indirect cost (×1,000 USD)        | 10.0           | 36.6           | 37.9           | 84.4           |
| Total project costs (×1,000 USD)  | 53.4           | 195.6          | 210.0          | 459.0          |
| Annualised costs: (USD/garden/year) | 47.8           | 23.3           | 21.5           | 23.2           |
| - Project costs¹                  | 35.6           | 11.2           | 9.3            | 11.1           |
| - Women’s opportunity cost        | 9.8            | 9.8            | 9.8            | 9.8            |
| - Seed supplies                   | 2.3            | 2.3            | 2.3            | 2.3            |

¹Total project costs divided by the number of home gardens established divided by the time span of the impact, which was assumed to be 5 years.

| Table 9. Potential contribution of the home garden intervention to closing the nutrition intake gap. |
|----------------------------------|----------|---------|--------|--------|
| Veg. (g)                         | Calcium (mg) | Iron (mg) | Zinc (mg) | Vit. A (mcg) | Folate (mcg) | Vit. C (g) |
| Per capita RNI of the study population² | 200.0    | 1,002.7 | 18.4   | 6.9    | 569.0       | 603.3       | 38.3   |
| Nutrient supply from:           |           |         |        |        |            |            |        |
| - Standard home garden (control group)² | 48.2    | 24.1    | 0.4    | 0.3    | 300.9       | 17.6        | 8.5    |
| - Impact of home garden intervention² | 16.5   | 31.5    | 0.3    | 0.2    | 282.8       | 16.5        | 13.9   |
| Per cent of RNI supplied by intervention² | 8.2    | 3.1     | 1.8    | 3.4    | 49.7        | 2.7         | 36.3   |
| Mean intake Bangladesh³          | 167.0    | 439.0   | 11.0   | NA     | 388.0       | 328.3       | 84.8   |
| Current intake gap (%)³         | 16.5     | 56.2    | 40.4   | 36.1   | 31.8        | 45.6        | –      |
| Reduction in gap due to intervention (%)³ | 49.9   | 5.6     | 4.5    | 8.0    | 100.0       | 6.0         | –      |

²Calculated from sex- and age-specific recommended nutrient intake (RNI) levels provided by Nahar et al. (2013) (p. 32–34) and the average household composition from the 2014 survey.
³Values for the control group (2014) as shown in Table 6.
⁴Average treatment effect reported in Table 6.
⁵Calculated as: Average treatment effect /RNI of the study population × 100.
⁶Taken from Nahar et al. (2013) (p. 35, 49) for lack of site-specific data.
⁷Mean intake Bangladesh divided by the RNI of the study population.
⁸Calculated as: (1 – Intake gap after intervention /Intake gap at status quo) × 100.
⁹Retinol equivalents; 1 IU of vitamin A was assumed equal to 0.3 mcg of retinol.
¹⁰Mean intake values provided by Nahar et al. (2013) were expressed in folic acid; these were converted to folate assuming 1 mcg of folate = 0.6 mcg of folic acid.
For the micronutrients covered in this study, data on DALYs were available for iron, vitamin A and zinc deficiencies from IHME (2015) and the analysis therefore focused on these three micronutrients. The results should be interpreted as a conservative estimate of the total contribution of home gardens to micronutrient deficiencies, as the intervention would be more cost-effective if other micronutrients were also considered.

Based on the estimated reduction in the nutrient intake gaps for iron (4.5 per cent), vitamin A (100 per cent) and zinc (8.0 per cent), we assumed a reduction in DALYs by the same percentages. This would mean a total of 122,610 DALYs saved if the intervention could reach all households affected by iron, vitamin A and zinc deficiencies (Table 10). Akhtar et al. (2013) reported that 51 per cent of pregnant women had diets deficient in vitamin A. Although not all households are affected, we conservatively assumed that 50 per cent of households in Bangladesh (~16.5 million households) are affected by either iron, vitamin A or zinc deficiencies. Reaching these many households with a home garden intervention, assuming no economies of scale, would cost US$375.1 million (US$23.2 × 16.5 million) per year. This implies a cost of US $3,059 per DALY saved.

Dividing the cost per DALY saved by the national per capita income level in Bangladesh, which was US$1,097 in 2014 (The World Bank 2015), suggests cost-effectiveness of 2.8 for iron, vitamin A and zinc deficiencies combined. The WHO suggests that a health intervention can be considered ‘cost-effective’ if the ratio is below 3 and ‘very cost effective’ if it is below unity (Asare-Marfo et al. 2014). By this standard, training of women in home gardening and nutrition can be considered a cost-effective strategy to address the health effects caused by iron, vitamin A and zinc deficiencies; however, given that other micronutrients are supplied by the home garden as well, this represents a conservative estimate and the true cost-effectiveness is likely to be higher.

### 3.5. Sensitivity analysis

Critical variables in the cost-effectiveness analysis are the assumed opportunity cost of women’s time spent on training and home gardening and the assumed nutrient losses between vegetable harvest and intake. We tested the effect of these assumptions on the cost-effectiveness ratio (Table 11). It confirms that the results are sensitive to these two variables, with the cost-effectiveness ratio ranging from 1.6 (assuming zero losses and zero opportunity costs) to 6.8 (assuming the full daily minimum wage rate and 50% nutrient losses). However, based on our knowledge and observations, we believe that valuing women’s gardening time at 50 per cent of the daily minimum wage rate and 0 per cent food waste and nutrient losses are the most realistic assumptions.
4. Discussion

Our results show that training women in home gardening and nutrition increased the household vegetable supply by 31 kg per year or by 16.5 g/capita/day – contributing 8.2 per cent of the recommended daily intake of vegetables. This increase in vegetable supply is relatively low in comparison to those reported by previous studies. Bushamuka et al. (2005) used a 3-month recall for the end of the rabi season and estimated a median monthly increase of 30 kg (~360 kg/year). Schreinemachers et al. (2015) used a 12-month recall period and estimated a mean annual increase of 80 kg. The large variation in harvested quantities shows the importance of estimating harvested quantities as part of an impact evaluation: the increase in home garden production is perhaps not a primary indicator of nutritional outcomes, yet it is a necessary precondition for achieving better micronutrient status through home gardens.

The study is one of the very few studies that separated the production effect of a home garden intervention between rabi and kharif seasons. Unfortunately, this showed that there was no impact of the intervention on garden vegetable supplies during the hot and dry (rabi) season when vegetables are relatively scarce. This is likely because of water shortages, as one-third of the trained women mentioned this to be a limitation. It is noted that the 2013 rabi season was relatively hot and dry, which is likely to have affected the results. It is therefore critical to address production constraints during the dry and hot season. It also shows the importance of capturing season variation in evaluation designs.

This study was the first to perform a cost-effectiveness analysis of a home garden intervention aimed at addressing micronutrient deficiencies. The clear advantage of a home garden intervention is its ability to concurrently address multiple micronutrient deficiencies, yet data limitations forced us to focus on iron, vitamin A and zinc, which are nevertheless the main micronutrient deficiencies affecting Bangladesh. A further data limitation was the absence of detailed nutrient intake data from our sample, which required us to use secondary data on the mean intake levels at a population level. These data limitations would need to be addressed in future studies.

A critical assumption was the opportunity cost of women’s time spent on training and gardening. If women’s time is valued at the minimum daily wage rate, then the intervention is not cost-effective with regard to the three micronutrient deficiencies considered – although it might still be cost-effective considering the full range of benefits. The question is whether the 7 min per day that women on average spent in the garden came at the cost of leisure time or productive time otherwise spent on childcare and other household chores. Another study on the same home garden project in Bangladesh showed that women gained self-esteem by being recognised for their agricultural skills in the community (Patalagsa et al. 2015). This suggests that noneconomic motives might be more important and that valuing women’s gardening time at the daily wage rate underestimates the true cost-effectiveness of the intervention.

The results suggest that interventions promoting home gardens and nutrition are cost-effective, even if only three key micronutrients are considered. Yet when comparing the benefits of home gardens to other health interventions, it is important to keep in mind that home gardens directly influence some of the causes of micronutrient deficiencies (that is, low food consumption and low diversity of food consumption), while micronutrient supplementation, fortification and biofortification

### Table 11. Sensitivity of the cost-effectiveness analysis to alternative assumptions about the valuation of women’s time and nutrient losses between vegetable harvest and intake.

| Opportunity cost of women’s time (% of daily minimum wage rate) | Food waste and nutrient losses (% of harvested quantity) |
|---------------------------------------------------------------|--------------------------------------------------------|
|                                                               | 0%           | 25%       | 50%       |
| 0%                                                            | 1.6          | 1.9       | 2.8       |
| 50%                                                           | 2.8          | 3.4       | 4.8       |
| 100%                                                          | 4.0          | 4.8       | 6.8       |
address symptoms rather than causes. Cost-effectiveness should therefore not be the sole criterion in the comparison with alternative health interventions. The benefits of home garden interventions go beyond micronutrients as they contribute to dietary diversification (an important welfare indicator in its own right), women empowerment, and other social and economic functions. Furthermore, because the effectiveness of home garden interventions tends to vary throughout the year, mostly as affected by weather, and because they do not close the micronutrient intake gap for micronutrients other than Vitamin A, home garden interventions are best seen as complementary to other interventions such as micronutrient supplementation, fortification and biofortification.

5. Conclusion

Training women of eligible households in rural Bangladesh in home gardening and nutrition significantly increased the per capita supply of vegetables by 16.5 g/day, most of which was consumed within the own household. It also led to an increased diversity of vegetables in the households’ diets. By WHO standards, the intervention is a cost-effective approach to address micronutrient deficiencies among poor rural households in Bangladesh, thereby contributing to food and nutrition security. Home gardens can be a useful food-based strategy to promote better balanced diets among poor rural households that have access to a small plot of land and are willing to engage in gardening. Home gardens can complement other interventions such as micronutrient supplementation, fortification and biofortification.

Note

1. Some economies of scale are likely if implementing the programme nationwide. However, costs might increase for reaching households in remote areas or in areas with more serious production constraints. Therefore, no economies of scale were assumed.

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