The effect of women's home gardens on vegetable production and consumption in Bangladesh

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Abstract

Home-based vegetable production has been recognized as a nutrition- and gender-sensitive intervention that has the potential to improve nutrition in developing countries, yet evidence is lacking. This study tested whether women's training in improved home gardens (including nutrition as well as technical aspects) contributes to increased production and consumption of vegetables, which are necessary preconditions for improving nutrition. The study used data from 582 poor rural women in two districts of Bangladesh (479 control and 103 intervention). The results show that the intervention increased the per capita production of mostly leafy vegetables from 20 to 37 kg per year (+86%). The diversity of production and frequency of harvesting also increased. In terms of nutrient yields, the improved gardens increased the supply of plant proteins by 171%, iron by 284%, vitamin A by 189% and vitamin C by 290%. The training had a significant impact on the diversity of vegetables consumed based on 30-day food frequency data. The training also increased the relative involvement of women in the home garden for all gardening tasks. These results indicate that women’s home gardens are an effective intervention in Bangladesh to increase the supply and consumption of a diverse range of vegetables in poor rural households, thereby contributing to nutrition security.

1 Introduction

The diets of around 2 billion people remain deficient in minerals and vitamins (FAO 2012). Together with hunger, malnutrition is a key constraint to human health in developing countries. Improving nutrition requires the adoption of balanced diets consisting of a diverse range of food products as no single food item contains all the necessary nutrients required for a healthy life. Fruits, vegetables, and pulses are key dietary components rich in micronutrients and plant proteins. Unfortunately, the consumption of fruits and vegetables in developing countries generally falls short of the recommended amount of 400 g/day (WHO/FAO 2003, Keatinge *et al.* 2011).

Home-based food production systems have received renewed interest in recent years because they have the potential to contribute to improved household nutrition (Berti *et al.* 2004; Chadha *et al.* 2012; Gautam *et al.* 2009; Jaenicke and Virchow 2013, Girard *et al.* 2012; Jones *et al.* 2005; Olney *et al.* 2009; Weinberger, 2013). A home garden is an area around a dwelling where different vegetables, fruits and herbs are grown throughout the year for a household's own consumption, potentially integrated with animal production (Keatinge *et al.* 2012). Such gardens can contribute to improved nutrition by increasing the quantity and quality of foods produced and available for household consumption. Women usually do gardening as well as food preparation. Therefore, the combination of nutrition education and counseling with the promotion of home gardens can be particularly effective (Berti *et al.* 2004).

However compelling the concept, scientific evidence for the effect of home gardens on nutrition is still weak. In a review of literature on the effect of nutrition-sensitive interventions and programs on maternal and child nutrition, Ruel *et al.* (2013: 539) concluded that there is little evidence of the effectiveness of homestead food production, with the possible exception of vitamin A status. Girard *et al.* (2012) reviewed more specifically the effect of household food production strategies on nutrition and concluded that the evidence is largely grounded in a limited number of studies, most of which had significant methodological limitations.

Against this background, the objective of this study is to test the hypothesis that home vegetable gardens contribute to nutrition security in Bangladesh. More specifically, we studied the short-term effect of women's home vegetable gardens on their vegetable production, households' consumption, and dietary diversity in two rural districts of Bangladesh. This study focuses on the immediate effects, and it does not evaluate the changes in nutritional status (anthropometry or micronutrient status). However, production and consumption of vegetables are necessary preconditions for such changes to occur through home vegetable garden interventions.

Bangladesh has achieved a marked decrease in both poverty and hunger, albeit from initially high levels. The poverty headcount ratio (at US$1.25 a day) decreased from 56.6% in 1992 to 31.5% in 2010 (World Bank 2013). The prevalence of undernourishment decreased from 34.6% in 1990-92 to 16.8% in 2010-12 (FAO 2013). Yet, the prevalence of malnutrition in rural Bangladesh is still among the highest in the world (*ibid.*). For example, stunting affects 42.2% of the female and 40.7% of the male children under the age of five (World Bank 2013). A recent study found high prevalence levels of vitamin A deficiency, iron deficiency, and zinc deficiency among preschool children and non-pregnant and non-lactating women (icddrb, b et al. 2013). Increased vegetable consumption could help improve nutrition, but consumption is still below the WHO-recommended amount of 200 g/day. Mia *et al.* (2013) estimated vegetable consumption for mothers in three districts (Jessore, Barisal and Faridpur) to be 117 g/day, of which only 3 g/day were leafy vegetables.

In Bangladesh, home gardens have been promoted for decades by international and local NGOs as well as the Bangladesh Agricultural Research Institute (BARI) (Talukder *et al.* 2000; Bloem *et al.* 1996). For example, Helen Keller International has established home gardens for 900,000 households since 1990, combined with nutrition education (Iannotti *et al.* 2009). The home gardens increased the quantity of the households' food production within three months from 46 to 135 kg (Helen Keller International 2004) and increased vitamin A intake among women and children (Bushamuka *et al.* 2005). Kumar and Quisumbing (2011) also conducted an evaluation of home vegetable gardens in Bangladesh. They evaluated the effects of improved vegetable varieties on income and nutrition with an intervention aimed at women's small-scale vegetable production in Saturia district (near Dhaka). Using data from 1996 and 2006 for 313 control and treatment households, they separated the immediate and sustained effects of adoption. They found negligible monetary gains; nevertheless there were sustained improvements in the nutritional status of women and children for early adopters of improved varieties. However, the intervention did not include nutrition education and counseling.

2 Methodology

2.1 Intervention and targeting

AVRDC – The World Vegetable Center has implemented home vegetable gardens in Bangladesh since the early 1990s. From 1991 to 1999, these gardens were implemented in partnership with Helen Keller International. Since 2011, AVRDC has worked with BRAC, a large international nonprofit organization based in Bangladesh. BRAC provides services such as microcredit, agricultural research and extension, primary education, legal aid, and public health in nearly all rural areas of Bangladesh. The home garden intervention evaluated in this study is part of a USAID-funded project. One of the aims of the project is to train several thousands of women in nutrition and improved home gardens in a year. In 2013, 3,500 women received training.

Those eligible for receiving project support had to meet the following criteria: First, the household must own some land but not more than one acre (0.4 ha). This ensures that the intervention targeted smallholder households. Yet, it excluded the landless poor who are likely to have the highest prevalence of malnutrition. Home gardens are not a suitable intervention for this group. Second, priority was given to households with at least one child below the age of five. Third, the women must have some experience in growing vegetables, but have not previously received any similar type of intervention. Also, they must have an interest to participate in the project.

The intervention focused on the introduction of improved nutrient-rich vegetable varieties suitable to grow in a home garden. It included water spinach (kangkong; *Ipomoea aquatica*), Indian spinach (Malabar spinach; *Basella alba*), stem amaranth/red amaranth (*Amaranthus* spp.), okra (*Abelmoschus esculentus*), yard-long bean (*Vigna unguiculata* subsp. *sesquipedalis*), cucumber (*Cucumis* spp.), sweet potato (*Ipomoea batatas*) for vines and young shoots, and bitter gourd (*Momordica charantia*). The vegetable varieties used were locally available. Households could select these, but they were also free to grow other vegetables and fruits.

Women received one-day intensive training focusing on nutrition and garden establishment. Training sessions took place at local BRAC training centers in early 2012. Two instructors managed the training and there were 10-15 women participants per session. Classroom teaching generally took 3-4 hours while hands-on practice in a demonstration garden lasted 1-2 hours.

The nutrition training taught the importance of nutrition in preventing diseases, functions of various nutrients in the human body, nutritional value of commonly consumed vegetables, and the availability of nutrients in different colors of vegetables. It also taught cooking methods that optimally preserve the nutritional content of vegetables.

The technical part of the training covered aspects such as site selection, site and land preparation, garden layout and design, seedbed preparation, seasonal vegetable selection, sowing practices, fertilization, irrigation and drainage, weeding, and insect and disease management without pesticides. Although home gardens are common in Bangladesh, this improved home garden design differs from usual practices as it made use of raised seedbeds, taught the women how to better plan their gardens, constructed fences with synthetic nets and locally available materials to keep out farm animals, and used better quality seeds. The training participants were encouraged to share the learned knowledge with neighboring women after the training.

Each training participant was visited 7-14 days after the training by a BRAC training officer to provide assistance in setting up the garden. Women would receive seed packs for growing the seven vegetables listed above and vines for planting sweet potato after the officer observed that the seedbeds were nearly complete. The BRAC officer visited the home gardens of the trained women on a weekly basis for the first six months of the training. Production and harvesting activities of the women would be recorded and technical questions from the women were answered. During the second six months, the visiting frequency was reduced to a monthly basis. A total of 26 BRAC staff were involved in the project from the two districts.

2.2 Methodology

Selection bias is often a problem in cross-sectional data when households have not been randomly assigned to control and intervention groups. There can be different sources of selection bias; but the main one is usually that households with certain favorable characteristics will self-select in adopting the technology earlier than others. As a result, the intervention group becomes a biased sample that is not representative of the larger population of eligible households.

Yet, in this study we had good reasons to believe that selection bias was not an issue. First, self-selection bias did not occur because intervention households were selected by the project staff, not the households themselves. Hence, like in a randomized controlled trial, we were able to control who did and did not receive the training. If women themselves could have decided to sign up for the training, then selection bias would have occurred. For instance, younger or more nutrition-conscious women would have been more likely to join.

Second, selection bias by project staff was minimized by comparing women who had received the project intervention in 2012 with women who had already been identified by the project to receive the intervention in a subsequent year. We thus made use of the roll-out design of the project to identify a valid counterfactual. The fact that the same targeting criteria were applied to select the intervention and control group ensured that the two groups are truly comparable. Although the project targeted different villages each year, there are no evident reasons to believe that the two groups have different characteristics (observable or unobservable) prior to the project intervention.

Third, selection bias also did not occur from the fact that selected women voluntarily chose not to receive the training. All women who had been selected by the project attended the training. This is because one of the selection criteria was that women must have an interest to participate in the project. Women not interested in home gardens were therefore excluded from the intervention as well as from the control groups.

Absence of selection bias can partly be verified by testing for significant differences in some key variables that can affect project outcomes such as land size, women's age, and home compound area. If there are significant differences in these observable characteristics, then matching estimators can be used to estimate the average treatment effect.

2.3 Data

Data were collected from two districts, Barisal and Jessore, where the intervention had taken place in 2012. To represent the intervention area, four upazilas (*i.e.* subdistricts) were purposively selected in each district (Table 1). Unions, the smallest rural administrative unit in Bangladesh and typically consisting of nine villages, were randomly selected from each upazilla's intervention area; while unions in the control group where purposively selected to have similar characteristics. Sample villages were selected from a list of all villages in the selected unions. Within each village, 10-15 households were sampled randomly from the list of women who had or would participate in the training. Only women were interviewed for this study and all agreed to participate. The data were collected using a structured questionnaire during April-May 2013.

Table 1 Sample selection

Administrative level	Control	Intervention	Total
Districts	2	2	2
Subdistricts (upazillas)	4	2	4
Unions	14	5	17
Villages	31	10	40
Households	479	103	582

The survey included 103 women who received the intervention in 2012 and 479 women who were used as the control group. The control group was relatively large because it included women who will receive the intervention in 2013 and in subsequent years. The survey will be repeated in 2014 to create a panel data set.

The study used a range of outcome indicators to quantify the effect of home vegetable gardens on households' vegetable production and consumption. Production data were collected using a 12-month recall period, separated for the two main seasons in Bangladesh (summer and winter). Indicators included the quantity of harvested produce from the garden and the frequency of planting and harvesting. Harvested quantities were recorded for 28 vegetables, which were divided into five groups: cucurbits and eggplants, roots and tubers, beans and pulses, leafy vegetables, and other vegetables (e.g. okra, cabbages, tomato, onion). Each group also contained a category "other".

Per capita production data were converted into nutrient yields using food composition tables taken from USDA (2014) for 22 vegetables and from AVRDC (2014) for four traditional vegetables not included in the USDA database (snake gourd, country bean, stem amaranth and red amaranth). Nutrients considered in this study included protein, calcium, iron, vitamin C and vitamin A. These are nutrients that are commonly measured in research studies of this kind. The provitamin A contents of vegetables was converted to vitamin A levels using retinol activity equivalents following USDA (2014). Nutrient conversion factors for the category "other" and two vegetables for which factors were unavailable (bottle gourd leaf, radish leaf) were replaced with the quantity-weighted average for all other vegetables in the same group.

Consumption data were collected using a 30-day food frequency questionnaire. The questionnaire included 30 locally consumed vegetables and respondents were asked to indicate whether they consumed the item (a) for 16-30 days during the last 30 days (that is, at least every other day), (b) 4-15 days, (c) 1-3 days, or (d) not at all. This method follows Hoddinott (1999), but we adjusted it by only recording the consumption of vegetables. A vegetable diversity index was calculated from the data. To do this, we first weighted each food item by the frequency of consumption; the assigned weights were 24, 10, 3 and 0 for categories (a) to (d) as suggested by Hoddinott. The weighted sum was converted into an index by first subtracting the minimum value of this variable as observed in the data and then dividing it by the difference between the maximum and minimum values. According to Hoddinott, the method has a low chance of misreporting and the consumption of a wide variety of foods is an important welfare indicator in its own right.

3 Results

Control and intervention households did not significantly differ in observable household characteristics, other than the average number of children below five years (Table 2). Including the variables in a probit function with the assignment of households to the control or intervention group as dependent variable shows that the explanatory power of the observable household characteristics is low (the pseudo R^2 is 4.9%). This suggests the absence of selection bias. Therefore, the control and intervention groups can be meaningfully compared, and the use of matching methods to correct for selection bias is not justified.

Table 2 Household characteristics of intervention and control groups (average per household)

Household characteristic	Control		Intervention		Sign.
	Sample mean	Standard deviation	Sample mean	Standard deviation	
Household size (persons)	4.74	1.44	4.63	1.58	
Adults (persons)	2.83	1.14	2.95	1.22	
Children below 5 years (persons)	0.63	0.58	0.34	0.52	***
Children 5-17 years (persons)	1.29	0.99	1.34	1.03	
Male household members (%)	48.76	16.71	47.99	17.60	
Female household members (%)	51.24	16.72	52.01	17.60	
Age of the main woman in the household (years)	35.70	10.21	37.40	9.81	
Cultivatable land (m^2)	2,360	1,760	2,533	3,219	
Cultivatable land owned by the household (%)	61.03	42.44	67.50	42.50	
Area of the compound (m^2)	534.85	508.35	451.74	334.32	
Cultivatable area on the compound (m^2)	43.66	17.92	44.90	12.89	
Received credit (%) [a, b]	48.85	50.04	41.75	49.56	
Months with not enough food to eat [a]	2.31	1.85	2.44	1.95	
Households who experienced a food shortage (%)[a, b]	79.61	40.49	76.41	42.50	

Notes: Significance levels: ***p<0.01, **p<0.05, * p<0.10. Sample size is 479 for the control and 103 for the intervention group. [a] Refers to the past 12 months. All other variables refer to the situation at the time of the interview. [b] Difference in means tested using Pearson's chi-squared test. Two sample t test was used for all other variables.

3.1 Vegetable production and consumption

The data in Table 3 show that all women who received the training cultivated a home vegetable garden in 2012. It also shows that home gardens are common in Bangladesh, because a majority of the women in the control group (69%) were also cultivating one. Yet, women who had received the training made significant changes in their home vegetable gardens. On average, women that had been trained made eleven different types of changes. More than 90% of the trained women had adopted improved bed systems, new crops, quality seed, improved fencing, and relay cropping. More than 75% had adopted irrigation, stalking/sticking or trellising methods, pruning methods, and organic fertilizers.

The intervention enabled women to plant and harvest vegetables more regularly during summer and winter. The women in the intervention group harvested on average, 108 times;

this was only 34 times for the control group. The average number of months with regular harvesting increased from 4 to 10. Despite the increased harvesting frequency, the improved home vegetable gardens did not provide vegetables on a daily basis (Table 3).

Table 3 The effect of women's training in home gardens on garden management (average per household)

Home garden characteristic	Control [a]		Intervention		Sign.
	Sample mean	Standard deviation	Sample mean	Standard deviation	
Cultivating a home garden (%) [c]	69	46	100	0	***
Received home garden training (%) [c]	0	0	100	0	***
Land area used for home garden (m2)	17.37	23.97	44.98	12.96	***
Months with daily harvesting	0.05	0.61	0.27	0.87	***
Months with regular harvesting [b]	3.98	3.56	10.16	2.21	***
Summer					
No. of different crops planted	1.03	1.27	6.01	1.13	***
Planting frequency	1.06	1.32	7.81	2.62	***
Harvesting frequency	15.62	21.87	63.20	24.81	***
Winter					
No. of different crops planted	1.23	1.30	4.54	1.68	***
Planting frequency	1.25	1.33	5.86	2.97	***
Harvesting frequency	18.21	21.54	44.81	23.54	***

Notes: Significance levels: ***p<0.01, **p<0.05, * p<0.10. Sample size is 479 for the control and 103 for the intervention group. [a] Includes data for households who did not cultivate a home garden. However, significance levels do not change if excluding control households without a home garden. [b] Harvesting more than once a week. [c] Difference in means tested using Pearson's chi-squared test. Two sample t test was used for all other variables.

The average amount of vegetables harvested from the home garden was significantly (p<0.01) greater for the intervention group (37 kg/capita/year) than for the control group (20 kg/capita/year) (Table 4). This suggests that the training led to an 86% increase in the quantity of vegetables harvested from the garden. Of the average increase in harvested quantity, 67% can be attributed to women adopting a home garden, while 33% can be attributed to higher output of existing home gardens.

Table 4 The effect of women's training in home gardens on harvested quantity and nutrient yield, per capita per year

Vegetable group	Total harvest (kg)					Plant proteins (g)				
	Control [a]		Intervention		Sign.	Control [a]		Intervention		Sign.
	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Cucurbits	11.08	27.22	11.93	28.91		77.91	183.13	84.40	189.42	
Roots and tubers	0.58	4.13	1.56	2.73	**	10.37	69.92	24.35	49.42	*
Beans and pulses	3.70	10.72	2.58	4.79		104.55	303.46	72.75	135.05	
Leafy vegetables	3.26	7.45	16.90	15.77	***	110.20	258.65	617.10	595.20	***
Other vegetables	1.22	5.78	3.87	6.24	***	14.04	63.05	61.37	91.70	***
All vegetables	19.84	34.34	36.84	44.20	***	317.08	532.80	859.98	826.61	***
Potential % RDA[b]	-	-	-	-		2.05	3.42	5.40	5.33	***

Vegetable group	Vitamin A (mg)					Vitamin C (g)				
	Control [a]		Intervention		Sign.	Control [a]		Intervention		Sign.
	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Cucurbits	123.36	349.99	104.63	222.26		1.29	3.05	2.34	3.84	***
Roots and tubers	2.42	29.02	76.29	118.15	***	0.08	0.51	0.14	0.46	
Beans and pulses	19.18	55.66	13.40	24.85		0.49	1.40	0.40	0.72	
Leafy vegetables	32.63	79.51	319.62	269.64	***	0.78	2.67	8.05	8.09	***
Other vegetables	4.68	21.47	13.31	19.96	***	0.34	2.12	0.68	0.95	
All vegetables	182.26	394.70	527.27	462.15	***	2.98	6.04	11.62	10.63	***
Potential % RDA[b]	70.93	146.25	203.07	183.53	***	12.18	22.80	46.71	43.49	***

Vegetable group	Iron (mg)					Calcium (g)				
	Control [a]		Intervention		Sign.	Control [a]		Intervention		Sign.
	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Cucurbits	37.32	83.84	39.89	77.45		2.74	6.89	2.88	7.37	
Roots and tubers	3.91	26.26	9.57	19.06	**	0.13	1.43	0.38	0.54	*
Beans and pulses	51.31	150.92	25.86	55.05		1.16	3.34	1.01	1.82	
Leafy vegetables	54.58	128.48	320.03	299.39	***	4.99	11.96	29.24	28.95	***
Other vegetables	5.05	23.19	19.00	27.69	***	0.28	1.336	2.18	3.12	***
All vegetables	152.17	261.52	414.35	383.71	***	9.30	16.00	35.69	34.71	***
Potential % RDA[b]	3.71	6.44	10.26	9.71	***	2.45	4.23	9.30	9.36	***

Notes: Significance levels: ***p<0.01, **p<0.05, * p<0.10. Sample size is 479 for the control and 103 for the intervention group. Difference in means tested using a two sample t test. [a] Includes data for households who did not cultivate a home garden. [b] Calculated as the average potential daily nutrient supply divided by the recommended daily allowance (RDA), averaged over all households.

The results clearly show that leafy vegetables were the dominant type of vegetables for women who received the training, while cucurbits were the most important vegetable for the control group, accounting for 56% of the overall harvest. The results show that the intervention group harvested a significantly greater amount of leafy vegetables as well as roots and tubers, but there was no significant difference in the harvested amount of cucurbits, and beans and pulses. This suggests that the increase in harvest of leafy vegetables did not reduce the harvest of other crops.

The positive contribution of the home gardens becomes even more obvious when converting harvested quantities into nutrient yields using standard food-nutrient conversion factors. The intervention group produced significantly ($p<0.01$) greater quantities of plant proteins (+171%), calcium (+284%), iron (+172%), vitamin A (+189%), and vitamin C (+290%). The results do therefore provide conclusive evidence that the training greatly increased the supply of food nutrients to the household and that this increase was chiefly due to more intensive cultivation of leafy vegetables.

The improved home gardens potentially supplied 5.4% of the average household's protein needs, 9.3% of its calcium needs, 10.3% of its iron needs, over 100% of its vitamin A needs, and 46.7% of its vitamin C needs (Table 4). However, this potential supply might not be fully realized as some of the harvested quantity will be wasted, some nutrients will be lost during food preparation, and not all nutrients will be digested and taken up by the body.

To understand how increased home vegetable production affects the household diet, we also need to know how the harvested produce is used. Roughly three quarters of the homestead vegetable produce is consumed within the household (Table 5). Of the remainder, 14-15% is shared with other households and 13-15% is sold. Among the women in the intervention group, 54% sold some of their produce; while only 25% ($p<0.01$) did in the control group.. The annual amount of revenue the produce brings to the household is less than 1 USD for both the intervention and the control households. The results of the 30-day food frequency data showed that intervention households have a greater diversity in their vegetable consumption: On average, the intervention group consumed one additional type of vegetable ($p<0.01$), and their diversity index was slightly greater ($p<0.01$).

Table 5 The effect of women's training in home gardens on per capita vegetable production, the usage of the produce and the diversity of vegetables consumed

	Control [a]		Intervention		Sign.
	Sample mean	Standard deviation	Sample mean	Standard deviation	
Vegetable production (grams/person/day)	54.4	94.1	100.9	121.1	***
Usage of produce (%)					
Consumed in the household	71.4	21.8	71.8	14.0	
Shared with others	13.9	9.5	14.9	5.3	
Sold	14.7	23.0	13.4	16.5	
Number of different vegetables eaten	11.0	2.6	12.0	3.2	***
Vegetable diversity index	0.28	0.15	0.33	0.15	***

Notes: Significance levels: ***p<0.01, **p<0.05, * p<0.10. Sample size is 479 for the control and 103 for the intervention group. Difference in means tested using a two sample t test.

3.2 Gender

The time spent per day in the home garden by women was 10.6 minutes for the intervention group and 4.4 minutes for the control group (Table 6). The difference is significant even if compared to the control group women who already have a home garden. This suggests that women spent more time on the home garden after the training. Generally, children were not involved in the home garden, and this was not different between the control and intervention group (not shown). For all gardening tasks, the time allocation of women was higher in the intervention group than in the control group. Adult women in the control group provided about half of the labor for planting, weeding, watering and harvesting. Women in the intervention group provided about three-quarters of the labor for these activities. It suggests that the intervention increased the relative involvement of women. The participation of women in all tasks that involve money—buying inputs, selling produce, and receiving revenues—was significantly higher for the intervention group, but was still only about 30%.

Table 6 The effect of women's training in home gardens on their involvement in garden activities

	Control [a]		Intervention		Sign.
	Sample mean	Standard deviation	Sample mean	Standard deviation	
Total time spent on gardening (minutes/day)	4.4	5.2	10.6	2.8	***
Involvement per activity:					
Land preparation (%)	45.6	38.6	57.1	26.5	***
Planting (%)	53.7	41.5	77.7	23.0	***
Buying inputs (%)	10.4	25.4	29.7	36.4	***
Weeding (%)	51.5	40.5	78.0	22.9	***
Watering (%)	55.2	41.4	78.5	19.6	***
Harvesting (%)	55.5	40.1	88.5	15.0	***
Selling (%)	11.3	25.0	32.9	41.2	***
Receiving the revenues (%)	13.3	27.8	37.3	42.2	***

Notes: Significance levels: ***p<0.01, **p<0.05, * p<0.10. Sample size is 479 for the control and 103 for the intervention group. Data refer to adult women only. Difference in means tested using a two sample t test.

4 Discussion

Selection bias was minimized through the design of this study: self-selection bias was avoided as project staff decided who did or did not get the training; while selection bias from the project staff was minimized by using the roll-out design of the project to select the control group. Arguably, a randomized controlled trial design would have been the preferred method to eliminate selection bias as it randomly assigns households to intervention and control groups. However, the random assignment of project benefits to women in the target population would not have been the most cost-effective way to roll out a program as it complicates logistics. Trainers must follow up with each participant and thus have to travel large distances. Randomization is also practically difficult if there are no existing data that identify the women eligible for the intervention. For this study, there were no prior data available regarding a participant's eligibility. Each household had to be visited to determine their eligibility for the intervention. For these reasons, this study did not use a randomized controlled trial design.

As we only had cross-sectional data, we were unable to prove that the control and intervention groups had the same average levels of vegetable production and consumption prior to the intervention. Nevertheless, we found no reasons to believe that selection bias had affected the results. We confirmed our results by also estimating the average treatment effect of the main outcome indicators with propensity score matching using the nearest-neighbor matching method. This also showed that harvested quantity, per capita nutrient yields, and diversity of vegetable consumption were significantly greater for the intervention group than for the control group. Our results are therefore robust to the analytical method used.

The results of this study confirm the very positive effect of home gardens as reported by Bushamuka *et al.* (2005). Their study reported a median vegetable production of 135 kg over three months for households participating in a gardening program and 46 kg for the control. Kumar and Quisumbing (2011) did not quantify levels of vegetable production but showed a positive immediate effect of home gardens on food expenditures.

Our study showed that the contribution of home vegetable gardens to household income is negligible. Kumar and Quisumbing (2011) also showed that home gardens in Bangladesh did not contribute to income; they even showed a negative long-term (10 year) effect on household income and assets. It must be emphasized, however, that the objective of home gardens in our project was not to increase income. In the training, women were encouraged to consume the vegetables in their household rather than sell them. It must also be emphasized that it is problematic to compare across studies because home garden programs can be very different in the type and intensity of training, targeting, support, and vegetable varieties.

With regards to gender, the results suggest that home vegetable gardens helped empower women to some extent as their involvement in all tasks that involve money—buying inputs, selling produce, and receiving revenues—was significantly higher for the intervention group.

However, men still dominated these tasks and a clear gender gap thus persists in economic transactions. Women in the intervention group only spent 6 more minutes per day on the home garden than women in the control group. The small amount of extra time spent suggests that the intervention does not take away women's time from other important tasks such as child care. Our own conversations with the trained women also confirmed this. Still, there is a need for more qualitative studies to understand how home garden interventions affect the livelihoods of women and children.

Our study has two main shortcomings. First, although the immediate effect of home gardens is very positive, it does not guarantee that the intervention leads to sustainable improvements in vegetable production and consumption. To this end, a follow-up survey is planned to verify these results and produce a more robust estimate of the average treatment effect using a double difference method. Long-term monitoring is, however, also needed. Still, our results make an important contribution to the existing literature. To our knowledge, there are no previous studies for Bangladesh that have proven that home gardens actually lead to an increased year-round production of vegetables and increased diversity of vegetable consumption. For instance, Bushamuka *et al.* (2005) measured vegetable production only for a 3-month period; while Kumar and Quisumbing (2011) did not quantify vegetable production or consumption, and their study focused on the adoption of improved vegetable technologies rather than on home garden and nutrition training as such.

Second, the significant increase in the quantity of vegetables harvested and the diversity of vegetables consumed, as shown by our study, does not necessarily mean that micronutrient deficiencies are reduced. The absorption of nutrients by the human digestive system depends on a host of other factors, such as nutrient interactions and overall health status. To our knowledge, there are no published studies on the nutritional outcomes of home gardens in Bangladesh. Nevertheless, an increase in the production and consumption of vegetables are necessary preconditions for such nutritional improvements to occur through home vegetable garden interventions. Studies on nutritional outcomes are important to complement studies on the production and consumption effects of home gardens.

Despite the very positive results of the home garden training, the respondents revealed that they faced many challenges in managing their gardens. Many women mentioned that seeds were too expensive, or that they were unavailable in small packs suitable for home production. In addition, many women reported that some of their vegetables had been stolen or eaten by foraging livestock and other animals. Many women also mentioned limitations in accessing water.

5 Conclusion

A comparison of data for 103 women who received training in nutrition and in setting up a home vegetable garden and 479 women who did not indicates that the intervention: a) nearly doubled the area of the home garden; b) induced the growing of leafy vegetables; c) allowed the women to harvest more regularly from the garden; d) significantly increased per capita vegetable production and the potential food nutrient supply to the household; e) significantly increased the diversity of vegetable consumption; and f) strengthened women's control over the home garden, and significantly increased their involvement in activities that involve money. These positive findings show that combined training in improved home gardens and nutrition makes an effective contribution to nutrition security.

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