Baliki *et al. Agriculture & Food Security* (2022) 11:48
https://doi.org/10.1186/s40066-022-00388-z

Agriculture & Food Security

RESEARCH

Open Access

Impacts of a home garden intervention in Bangladesh after one, three and six years

Ghassan Baliki[1,2*], Pepijn Schreinemachers[3], Tilman Brück[1,2,4] and Nasir Md. Uddin[5]

Abstract

Background: Training women in home gardening and nutrition has been shown to increase household production and consumption of nutritious food and contribute to women's empowerment, but evidence is limited to short-term effects. Here, we investigate whether home garden support leads to long-term improvements in household nutrition and women's empowerment. To do this we use four waves of household-level survey data collected over a 7-year period (2013–2019) from an intervention ($n = 395$) and a control ($n = 224$) group in four rural districts of Bangladesh. We estimate the intent-to-treat effect using a difference-in-difference estimator.

Results: We find an immediate increase in the quantity of vegetables harvested from home gardens (+29.6 kg/year; $p = 0.01$) and this effect is sustained in years three (+42.3 kg; $p < 0.01$) and six (+37.0 kg; $p < 0.01$). The nutrient yield from the gardens also remained positive and significant, but the effect declined due to changes in the composition of vegetables. The effect on per capita vegetable intake, significant in years one and three, turned not significant in year six. Effects on nutrition knowledge, food preparation practices, and women's empowerment all remained significant in year six.

Conclusions: Home garden interventions in Bangladesh create sustained impact on a range of social, economic and nutritional outcomes. Refresher training after 5 or 6 years may help to maintain the full range of impacts observed.

Keywords: Nutrition-sensitive agriculture, Sustainability, Vegetable, Homestead food production, Micronutrient, Women's empowerment

Introduction

Home gardens make an important contribution to global food and nutrition security [4, 7, 8, 10, 16, 17, 24]. However, this contribution is usually not fully recognised in research and policy [23]. Nonetheless, the potential of home gardens is far from being realised as many home gardens suffer from low productivity and neglect. Past studies, listed below, have shown that home gardens can be made more productive with relative ease and low cost through targeted interventions that provide gardeners with hands-on training in gardening methods to increase production combined with training in nutrition to stimulate household demand for home garden produce.

The available evidence shows that home garden interventions can improve household production and consumption of vegetables [3, 5, 12, 17–19], nutritional outcomes such as reduced wasting and anaemia [13, 22], and reduced child diarrhoea [9, 13]. There is also evidence that home garden interventions contribute to women's empowerment [3, 9, 15, 21].

However, nearly all of the available evidence is based on studies either conducted during or immediately after project support ended. For instance, Olney et al. [13] studied the effect of a home garden intervention in Burkina Faso during the second year of a 2-year intervention programme; Kumar et al. [9] studied the impact of a

*Correspondence: baliki@igzev.de

[1] Leibniz Institute of Vegetable and Ornamental Crops, Theodor-Echtermeyer-Weg 1, 14979 Großbeeren, Germany
Full list of author information is available at the end of the article

home garden intervention in Zambia in the fourth year of a 4-year programme, Olney et al. [14] studied the impact of a 3-year home garden support programme in Cambodia 1.5 years into the programme, and Depenbusch et al. [5] studied the impact of home garden programme in Cambodia after one year. Baliki et al. [3] used a slightly longer time-span and studied the impact of a home garden intervention in Bangladesh 3 years after project support had ended. They found that the average impact on vegetable production and consumption was not statistically different between 1 and 3 years.

Zimpita et al. [26] is the only study that we are aware of that studied the long-term sustainability of home gardens. They revisited home gardens in South Africa 10 years after the intervention ended and found that about a third of the households continued to grow the same β-carotene-rich fruit and vegetables that had been introduced by the programme and that this proportion was very similar one, 6 and 10 years after the project. However, the study did not estimate the average treatment effect and did not include a counterfactual.

Against this background, the present study reports on the impact of a home garden programme in Bangladesh. The objective is to answer the question whether impact was sustained for 6 years after outside support ended, and if this impact is significantly less than what was observed after 1 or 3 years. Building on Schreinemachers et al. [18] and Baliki et al. [3], we collected another round of data for the same sample of households in Bangladesh. This study contributes to the existing literature on home gardens by using four waves of household data for the same households spanning a period of 7 years, which is unique in the impact literature. The importance of this is that it provides the first rigorous evidence ever of the long-term impacts of a home garden intervention.

Data and methods

Intervention design

The home garden intervention studied here was implemented from 2012–2015 by the World Vegetable Center in collaboration with two local non-governmental organisations (NGOs): BRAC implemented the intervention in Jashore and Barisal Districts, and Proshika implemented it in Patuakhali and Faridpur Districts. The project was funded by the United States Agency for International Development (USAID) and reached over 10,000 rural women.

Eligible households had to meet three criteria: (i) they had to have some land but not more than one acre (0.4 ha) to ensure that it targeted poor smallholder households (landless households were not targeted by this intervention); (ii) the woman had to have some experience in growing vegetables, but not have received similar support in the past; and (iii) the woman needed to have an interest to participate in the project. Households with a child below the age of five were prioritised by the project.

The intervention provided seed of improved (open pollinated) nutrient-rich vegetable varieties suitable for home garden cultivation: stem amaranth/red amaranth (*Amaranthus* spp.), bitter gourd (*Momordica charantia*), Indian spinach (*Basella alba*), okra (*Abelmoschus esculentus*), water spinach (*Ipomoea aquatica*), and yard-long bean (*Vigna unguiculata* subsp. *sesquipedalis*). The project also provides vines of sweet potato (*Ipomoea batatas*) for harvesting vines and young shoots; and seed of cucumber (*Cucumis* spp.) because of local preferences (although it is not as nutritious as the other vegetables). 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 about 10–15 women participants per session, which 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 vegetables of different colours. 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. Trainees were encouraged to share their new knowledge with neighbours.

Women received a follow-up visit 7 to 14 days after the training by the training officers who provided assistance in setting up the garden and answered questions. Women received seed packs for growing the seven vegetables listed above and vines for planting sweet potatoes after the officer had observed that the planting beds were near completion. Training officers visited the home gardens on an almost-weekly basis for the first 6 months of the training. The frequency was reduced to monthly visits for the second 6 months.

Evaluation design and data analysis

Eligible households were not randomly assigned to a control and intervention group and we therefore use a quasi-experimental evaluation design. We quantified the average treatment effect (intent-to-treat) employing a difference-in-difference (DID) estimator using this equation:

$$\begin{aligned} \text{Outcome } = & \alpha + \beta\,(\text{Treatment}) + \gamma\,(\text{Period}) \\ & + \delta\,(\text{Treatment} \times \text{Period}) + \varepsilon\text{i}, \end{aligned} \quad (1)$$

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. Parameter δ represents the average treatment effect. The model was estimated using ordinary least squares regression with robust standard errors. It was estimated for each of the three follow-up surveys against the same baseline survey.

Outcome variables

The outcome variables were the same as used in Baliki et al. [3] and Schreinemachers et al. [18]. Vegetable production was expressed in kilogrammes of fresh weight per household member per year, collected using a 12-month recall period that referred to the most recent summer (*kharif*) and winter (*rabi*) season. Vegetable production was disaggregated by five groups of vegetables: cucurbits and eggplants; roots and tubers; fresh beans and pulses; leafy vegetables; and other vegetables (e.g. okra, tomato. Vegetable production was also analysed by usage: home-consumed, shared with neighbours, or sold. Furthermore, vegetable quantities were converted to quantities of plant proteins, calcium, iron, folate, zinc, vitamin A (converted from pro-vitamin A and β-carotene contents) and vitamin C using food composition tables [20, 25].

Vegetable intake was quantified using a 24-h recall method that recorded quantities of 32 different kinds of vegetables consumed by the entire household. Respondents were asked for the quantity of raw vegetables used and the quantity of leftovers, which was deducted from the quantity used. Vegetable intake was expressed in grammes per capita per day. The 24-h recall data were, unfortunately, not recorded at baseline.

Secondary outcomes included the adoption of various good gardening practices that were taught during the training. Food and nutrition knowledge was measured using 12 statements that were factually correct or incorrect.[1] The knowledge score was the sum of correct answers, normalised to take values between 0 and 1. An example of an incorrect statement is 'Cooking vegetables for a long time makes them more nutritious.' We also measured nutrition-sensitive practices in terms of the average cooking time of vegetables.

Other secondary outcomes included a measure of women's self-perceived empowerment. Previous studies have shown that home garden interventions can make a positive contribution to gender equality [9, 15, 21]. We presented respondents with eight statements related to perceived social norms in the local cultural context.[2] Respondents could reply on a five-point scale from strongly agree to strongly disagree. For half of the statements, a lower score meant more empowerment and these were reverse coded before calculating the total empowerment score ranging from 0 to 32. We then normalised the index to take values between 0 and 1. Our measure of women's empowerment is relatively simple compared to more advanced tools such as the women's empowerment in agriculture index [1, 11].

A second variable included women's decision-making and control over the home garden. This is key to understanding the authority and agency of women over home garden management and production choices, which links directly with nutrition diversity [2]. For nine decisions relevant to home gardens, respondents were asked on a scale from 0 to 4 whether they or their husbands mostly made the decision. The nine variables were summed into a single variable that ranged from 0 to 36, where 36 indicates that all decisions were always made by the woman.

[1] The statements were: 1. Rice is an important source of vitamins and minerals (incorrect). 2. It is important for young children to eat food rich in proteins such as meat, pulses and dairy (correct). 3. Cooking vegetables for a long time makes them more nutritious (incorrect). 4. Carrots, pumpkins and orange sweet potatoes are all sources of vitamin A (correct). 5. Not eating enough vitamin A can result in eye disease (correct). 6. Pregnant women should avoid foods high in iron such as leafy vegetables (incorrect). 7. Stem amaranth is a very healthy vegetable (correct). 8. For a heathy diet it is important to eat a diverse range of foods (correct). 9. Eggplants and gourds are generally more nutritious than leafy vegetables (incorrect). 10. For children, eating rice and meat is more important than eating vegetables (incorrect).
11. You should first cut leafy vegetables and then wash them (incorrect). 12. Cutting vegetables in medium sized pieces is better than in tiny pieces (correct).

[2] The statements were: 1. The woman should make decisions on her own regarding children's health. 2. The man should make decisions by himself on how to spend the household money. 3. The woman should tell the man what food to buy and the man should do this. 4. The woman does not have to consult the man on what to cook for dinner. 5. The woman should always ask the man for permission to go outside the compound. 6. The man has the right to scold/beat his wife if she does something wrong. 7. The man should have the final word when making joint decisions. 8. The woman should always do what the man deems is best.

Again, we normalised this variable to values between 0 and 1. Both variables were collected only during the third and fourth waves of the survey.

Data collection

Data were collected from all four districts included in the project: Barisal, Faridpur, Jashore and Patuakhali. Three *upazillas* (subdistricts) were purposively selected from each district. Next, unions, the smallest rural administrative unit typically consisting of nine villages, were randomly selected from a list prepared by the NGO partners. We manually selected other unions with similar characteristics but within the same *upazillas* as a control. This approach minimised the chance that control households would learn the technology from intervention households. Sample villages were selected from a list of all villages in the selected unions. About 10–15 eligible households from each village were randomly selected to take part in the survey.

Grameen Bikash Foundation, a Bangladeshi NGO, conducted all four rounds of the survey. Data were collected in April–May during the end of the winter (*rabi*) season when home gardens are usually less productive because there is not much rain. All respondents were women and all selected women agreed to participate in the study. Enumerators explained the purpose of the study to the respondents before the interview and asked for their explicit verbal consent. Participation in the study was voluntary and considered to impose no risks to participants. World Vegetable Center did not have an institutional review board (IRB) at the start of the study, but based on current ethical guidelines the study would have been exempted from IRB review.

The sample size of the study has somewhat declined over time as some households no longer exist (migrated, died, split or otherwise). Sample attrition was 5% for the first follow-up, 6% for the second follow-up, and 12% for the third follow-up (Table 1). The sample with complete data across four waves is 595, including 380 households in the intervention group and 215 in the control, bringing the total attrition rate to 12%. There were no notable differences in baseline characteristics between attrited and non-attrited households.

Baseline differences in the means of outcome variables between the intervention and control groups were tested using a pairwise t-test for continuous variables and Chi-square test for categorical variables. This showed no significant differences in means (Table 2), which suggests that selection bias is not a problem in our data and confirms the earlier analysis of the same data as reported in Baliki et al. [3] and Schreinemachers et al. [18].

Table 1 Sample size used in the study, in number of households

Survey	Intervention	Control	Total
Baseline (2013)	425	252	677
1st follow-up (2014)	408	238	646
2nd follow-up (2016)	404	234	638
3rd follow-up (2019)	380	215	595
Panel sample with complete data for 4 surveys	380	215	595

Results

Impacts on technology adoption

Six years after the home garden intervention, project participants continued to use a range of home garden practices that had been taught in the training such as raised planting beds, inorganic fertilisers, and compost (Table 3). The average number of practices applied was 6.6 for project participants and 5.1 for the control group ($p < 0.01$). This shows sustainable adoption of some of the practices taught. The use of chemical pesticides was not taught during the training, but the previous studies showed that their use increased as a result of the intervention, which is an unintended adverse effect, which likewise persisted for the 6-year period.

Impacts on home garden production

The average treatment effect on the quantity of vegetables harvested from home gardens after 6 years is 36.97 kg/year ($p < 0.01$), which is 43% higher than the baseline mean (Table 4). This is not significantly different from the 1-year and 3-year effects. The interventions' impact on home garden vegetable production was therefore sustained for at least 6 years.

One year after the intervention, we found that most of the increased garden produce was home-consumed while a small amount was shared with neighbours. In the third year, households consumed most of their own produce, but also sold a substantial quantity. In the sixth year, the effect on own consumption remained significant, but the effect on sharing and selling was not. Therefore, the data show that households continued to use most of their increased vegetable harvest for home consumption.

The 1-year effect on vegetable production was largely due to an increase in leafy vegetable harvesting (+ 22 kg), but this effect was not observed in years three and six as most of the increase in those later years was attributable to eggplants and cucurbits (e.g. pumpkin, loofah, bitter gourd) and other vegetables (e.g.

Table 2 Mean baseline characteristics of the sample, 2013

	Intervention (*n* = 380)	**Control (*n* = 215)**	***p*-value**
Household size (persons)	4.85 (1.51)	4.97 (1.56)	0.365
Men (persons)	2.36 (1.07)	2.48 (1.20)	0.211
Women (persons)	2.49 (1.17)	2.49 (1.13)	0.970
Adults (persons)	2.85 (1.14)	2.99 (1.22)	0.176
Children under 5 (persons)	1.39 (1.02)	1.31 (1.05)	0.366
Children < 12 months (persons)	0.61 (0.60)	0.67 (0.62)	0.237
Cultivated a garden (1 = yes)	0.70 (0.46)	0.75 (0.43)	0.138
Garden size (m2)	20.87 (28.05)	18.63 (22.19)	0.283
Garden practices (number)	0.02 (0.12)	0.02 (0.20)	0.626
Challenges in gardening (number)	0.57 (1.07)	0.71 (1.14)	0.140
Women involved in garden (1 = yes)	70.08 (20.02)	69.32 (20.70)	0.713
Men involved in garden (1 = yes)	26.45 (19.55)	27.84 (19.71)	0.480
Children involved in garden (1 = yes)	3.47 (7.56)	2.83 (6.68)	0.364
Garden production (kg/year)	86.77 (125.67)	87.04 (129.07)	0.980
Garden production summer season (kg)	38.17 (75.50)	37.89 (84.32)	0.968
Garden production winter season (kg)	48.60 (84.62)	49.15 (81.26)	0.938

Means with standard deviations in brackets. Sample was restricted to households for which we have data for 2013, 2014, 2016 and 2019

Table 3 Use of various garden practices at long-term endline between intervention and control

Garden practice	**Intervention (*n* = 380)**	**Control (*n* = 215)**	***p*-value**
Raised beds	0.51 (0.50)	0.37 (0.48)	0.001
Inorganic fertiliser	0.61 (0.49)	0.37 (0.48)	< 0.001
Composting	0.49 (0.50)	0.31 (0.46)	< 0.001
Chemical pesticides*	0.69 (0.46)	0.44 (0.50)	< 0.001
Biopesticides	0.68 (0.47)	0.37 (0.48)	< 0.001
Mulches	0.27 (0.45)	0.16 (0.37)	0.001
Bagging fruits	0.13 (0.34)	0.05 (0.21)	< 0.001
Pruning	0.64 (0.48)	0.56 (0.50)	0.039
Stalking/trellis	0.92 (0.27)	0.85 (0.36)	0.017
Strong fences	0.79 (0.41)	0.68 (0.47)	0.005
Irrigation	0.91 (0.28)	0.91 (0.28)	0.950
Total number of practices	5.06 (2.49)	5.06 (2.49)	< 0.001

Means with standard deviations in brackets. Based on 2019 survey data. Welch two-sample t-tests with unequal variance

* Chemical pesticides were not recommended during the training

okra, tomato). Hence, the composition of vegetables has changed over time and the increased production of nutrient-dense leafy vegetables as observed after one year was not sustained.

The initial analysis showed that the impact of home gardens was largely confined to the summer season while the effect on the winter season was not significant. In contrast, the data for years three and six show that production increased both in the summer and winter seasons.

Some cucurbits like loofah are less nutrient-dense than leafy vegetables and the quantity of nutrients harvested from the home garden may therefore have changed. This was tested by converting quantities of vegetables to quantities of nutrients (Table 5). Average treatment effects for all micronutrients in year one were indeed higher than in year three, and average treatment effects for all micronutrients in year three were also higher than in year six. Yet, z-scores indicate that only for zinc is the 6-year effect is significantly lower than the 1-year effect. Furthermore, while the average treatment effects were significant for all seven nutrients tested in years one and three, the effects are insignificant for two nutrients (calcium and zinc) in year six. Hence, this provides evidence that the quantity of nutrients harvested, while still significantly positive on aggregate, has somewhat declined over the 6-year period.

Impacts on vegetable intake and nutrition knowledge

Vegetable intake was not enumerated in the baseline and we therefore simply compare means for the intervention and control 6 years after the intervention (Fig. 1). This shows that the significant effect on vegetable intake observed in year three had disappeared in year six as the mean quantity of the control and intervention are no longer significantly different.

The impact on food and nutrition knowledge remained significant after 6 years (Fig. 2A). The average cooking time of vegetables, an indicator for how many nutrients

Table 4 Impact of a home garden intervention on the quantity of vegetables harvested

Outcome	Baseline mean (SD)	1-year effect		3-year effect		6-year effect	
		ATE (SE)	p-value	ATE (SE)	p-value	ATE (SE)	p-value
Total vegetable production (kg/year)	86.87 (126.80)	29.56 (11.54)	0.01	42.27 (13.06)	< 0.01	36.97 (12.39)	< 0.01
By usage:							
Home consumed (kg/year)	50.53 (67.31)	26.78 (6.39)	< 0.01	29.18 (7.62)	0.00	26.79 (6.66)	< 0.01
Shared (kg/year)	11.54 (19.47)	4.63 (1.91)	0.02	1.92 (2.08)	0.35	1.30 (1.95)	0.51
Sold (kg/year)	24.80 (69.24)	-1.86 (6.02)	0.76	11.47 (6.44)	0.08	8.51 (6.78)	0.21
By season:							
Summer (kg/year)	38.07 (78.73)	27.44 (7.14)	< 0.01	21.07 (7.80)	0.01	19.96 (7.73)	0.01
Winter (kg/year)	48.80 (83.35)	2.12 (7.59)	0.78	21.21 (8.65)	0.01	17.01 (7.85)	0.03
By crop category:							
Eggplants and cucurbits (kg/year)	47.52 (90.30)	-11.85 (8.06)	0.14	24.13 (9.22)	0.01	17.85 (8.43)	0.03
Roots and tubers (kg/year)	1.94 (14.80)	2.84 (1.48)	0.06	0.84 (2.09)	0.69	0.53 (1.69)	0.75
Beans and peas (kg/year)	15.34 (38.91)	6.41 (3.43)	0.06	5.03 (3.65)	0.17	6.51 (3.49)	0.06
Leafy vegetables (kg/year)	15.63 (39.41)	22.21 (3.64)	< 0.01	4.76 (3.92)	0.22	3.32 (3.88)	0.39
Other vegetables (kg/year)	6.43 (30.20)	9.94 (2.77)	< 0.01	7.50 (3.71)	0.04	8.76 (3.5)	0.01

Year-1, -3 and -6 effects refer to 2014, 2016, and 2019, respectively

ATE average treatment effect, *SD* standard deviation, *SE* standard error

Table 5 Impact of a home garden intervention on the quantity of nutrients harvested, per capita per day

Outcome	Baseline mean (SD)	1-year effect		3-year effect		6-year effect	
		ATE (SE)	p-value	ATE (SE)	p-value	ATE (SE)	p-value
Total quantity (g)	52.46 (82.94)	14.78 (7.74)	0.06	21.68 (8.89)	0.01	17.55 (8.28)	0.03
Plant proteins (g)	0.86 (1.41)	0.71 (0.14)	< 0.01	0.39 (0.15)	0.01	0.29 (0.14)	0.04
Calcium (mg)	26.54 (47.85)	29.91 (4.87)	< 0.01	12.27 (5.27)	0.02	7.03 (5.18)	0.18
Iron (mg)	0.40 (0.68)	0.32 (0.07)	< 0.01	0.19 (0.07)	0.01	0.16 (0.07)	0.02
Folate (mcg)	19.15 (32.90)	15.29 (3.21)	< 0.01	8.03 (3.53)	0.02	6.61 (3.42)	0.05
Zinc (mg)	0.33 (0.57)	0.23 (0.05)	< 0.01	0.15 (0.06)	0.02	-0.04 (0.05)	0.43
Vitamin A (1000 UI)	0.76 (1.64)	0.97 (0.18)	< 0.01	0.63 (0.21)	< 0.01	0.61 (0.20)	< 0.01
Vitamin C (mg)	8.55 (16.67)	12.67 (1.71)	< 0.01	7.17 (2.11)	< 0.01	4.9 (2.03)	0.01

ATE average treatment effect, *SD* standard deviation, *SE* standard error

Year-1, -3 and -6 effects refer to 2014, 2016, and 2019, respectively

are retained during food preparation as vegetables are often overcooked in traditional cooking, remains negative and significant (Fig. 2B).

Impacts on women's empowerment

Women's control over the home garden is no longer significantly different between control and intervention in year six whereas it was significant in year three (Fig. 3A). Our data do not reveal why, but it is possible that men got more involved in the home gardens when they realised it was useful to the household. Yet, our simple measure of women's empowerment remains positive and significant in year six (Fig. 3B).

Discussion

The findings of the study show that 6 years after a home garden intervention in Bangladesh, the positive impact on vegetable production was maintained: the mean quantity of vegetables harvested from home gardens after 6 years is not less than after 1 or 3 years. However, beneficiary households switched from producing nutrient-dense leafy vegetables to eggplants and cucurbits, suggesting a weakened effect on micronutrient supplies. The switch in the vegetable composition may be because of cultural preferences, ease of cultivation or economic returns. More worrisome is that the significant effect on vegetable intake, observed in year three,

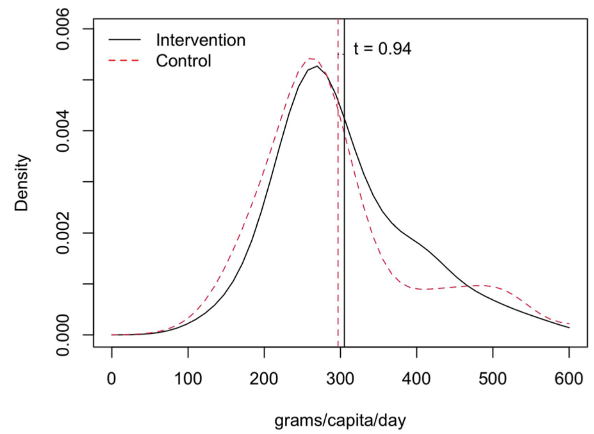

Fig. 1 Average daily per capita intake of vegetables in year six (2019)

had dissipated by year six. Yet, it has to be kept in mind that this is based on a single 24-h dietary recall that may not represent vegetable intake throughout the year. Moreover, the effects on food and nutritional knowledge and vegetable preparation remained positive and significant, and also the effect on women's empowerment was sustained.

Prior work analysing impacts of this intervention after one year estimated the cost-effectiveness of the home garden intervention [18]. It made the assumption that the impact of the home garden training would be sustained for 5 years, after which participants would need retraining. Based on three rounds of follow-up data, our study confirms the validity of this assumption. It also appears correct to recommend refresher training after 5 or 6

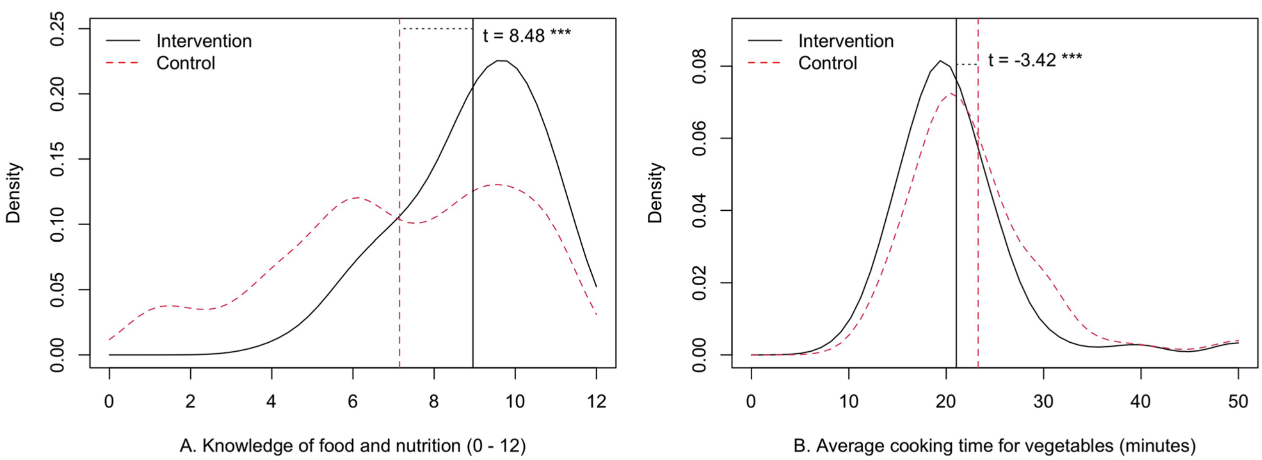

Fig. 2 Effect on food and nutrition knowledge (**A**) and average cooking time of vegetables (**B**) in year six (2019)

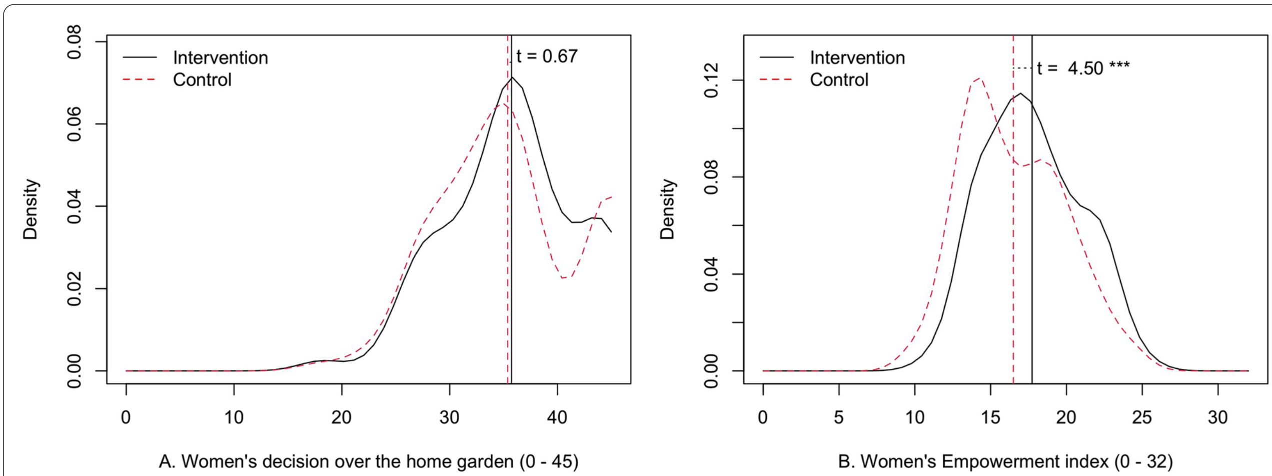

Fig. 3 Effect on women's decisions over the home garden (**A**) and women's empowerment (**B**) in year six (2019)

years as there are some indications that impact has weakened in year six. This is an important implication of our study, which could inform the design of home garden programmes globally.

Our study's strength is the use of four rounds of survey data collected over a 7-year period, which is unique in the home garden impact evaluation literature. Although this is not a randomised controlled trial, selection bias is not apparent in the data as the outcomes were balanced at baseline in 2013. Some outcome variables were added after the baseline, such as vegetable intake, food and nutrition knowledge and women's empowerment and these could not be analysed with the same rigour as the production-related outcomes, which is a weakness of the study. The data on per capita vegetable consumption also appear unrealistically high with a mean of about 300 g per day, which is a problem we also observed in other home garden evaluations [6] and relates to difficulties in accurately measuring vegetable quantities. Overall, the lack of good dietary data and other higher-level nutrition outcomes is a weakness of this study. Finally, like most other impact studies, we quantify the mean effect size, which has limitations as it ignores the heterogeneity of impacts across households.

For future research it would be useful to complement our quantitative analysis with more in-depth insights from qualitative research to better understand the reasons for certain changes to happen. For instance, we observed a switch from leafy vegetables to gourds without fully understanding why; and we observed that women's control over home gardens was significant in year three, but not in year six, so we need to try and understand why.

Conclusion

A home garden intervention in Bangladesh implemented in 2013 led to an immediate increase in the quantity of vegetables harvested from home gardens in 2014 and this effect was sustained for at least 6 years until 2019, alongside a range of other desirable impacts. This is important and novel evidence that the impact of home garden interventions can be sustainable. Refresher training of project participants after 5 or 6 years is recommended as the effect size and significance levels of some of the secondary outcome indicators was lower in the 6-year follow-up.

Acknowledgements
We thank this journal's editor and three anonymous reviewers for their helpful comments.

Author contributions
GB conducted the literature review, analysed and interpreted the data, and contributed to writing the manuscript. PS designed the study and drafted the manuscript. TB contributed to the research design and manuscript writing. NU managed the survey data collection. All authors read and approved the final manuscript.

Funding
Open Access funding enabled and organized by Projekt DEAL. Funding for this research was provided by the United States Agency for International Development (USAID) under the project "Improving incomes, nutrition, and health in Bangladesh through potato, sweet potato, and vegetables" and long-term strategic donors to the World Vegetable Center: Taiwan, UK Aid from the UK government, USAID, Australian Centre for International Agricultural Research (ACIAR), Germany, Thailand, Philippines, Korea, and Japan. The usual disclaimer applies.

Availability of data and materials
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The study uses household survey data collected via face-to-face interviews. Enumerators explained the purpose of the study to the respondents before the interview and asked for their explicit verbal consent. Participation in the study was voluntary and considered to impose no risks to participants. World Vegetable Center did not have an Institutional Review Board (IRB) at the time of start of the study, but based on current ethical guidelines the study would have been exempted from IRB review.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

Author details
[1]Leibniz Institute of Vegetable and Ornamental Crops, Theodor-Echtermeyer-Weg 1, 14979 Großbeeren, Germany. [2]ISDC—International Security and Development Center, Auguststr. 89, 10117 Berlin, Germany. [3]World Vegetable Center, P.O. Box 1010, Bangkok 10903, Thailand. [4]Thaer-Institute, Humboldt-University of Berlin, Unter den Linden 6, 10099 Berlin, Germany. [5]Grameen Bikash Foundation, Bogra, Bangladesh.

Received: 13 April 2022 Accepted: 13 August 2022
Published online: 10 September 2022

References

1. Alkire S, Meinzen-Dick R, Peterman A, Quisumbing A, Seymour G, Vaz A. The women's empowerment in agriculture index. World Dev. 2013;52:71–91.
2. Anderson CL, Reynolds TW, Biscaye P, Patwardhan V, Schmidt C. Economic benefits of empowering women in agriculture: assumptions and evidence. J Deve Stud. 2021;57(2):193–208.
3. Baliki G, Brück T, Schreinemachers P, Uddin MN. Long-term behavioural impact of an integrated home garden intervention: evidence from Bangladesh. Food Sec. 2019;11:1217–30.
4. Castañeda-Navarrete J. Homegarden diversity and food security in southern Mexico. Food Sec. 2021;13:669–83.
5. Depenbusch L, Schreinemachers P, Brown S, Roothaert R. Impact and distributional effects of a home garden and nutrition intervention in Cambodia. Food Sec. 2022. https://doi.org/10.1007/s12571-021-01235-y.
6. Depenbusch L, Schreinemachers P, Roothaert R, Namazzi S, Onyango C, Bongole S, Mutebi J. Impact of home garden interventions in East Africa: Results of three randomized controlled trials. Food Policy. 2021;104:102–40.
7. Dragojlovic N, Michaux KD, Moumin NA, Li KH, Talukder Z, Hou K, et al. Economic evaluation of an enhanced homestead food production intervention for undernutrition in women and children in rural Cambodia.

Glob Food Sec. 2020;24:100335. https://doi.org/10.1016/j.gfs.2019.100335.
8. Galhena D, Freed R, Maredia K. Home gardens: a promising approach to enhance household food security and wellbeing. Agric Food Sec. 2013;2(1):8.
9. Kumar N, Nguyen PH, Harris J, Harvey D, Rawat R, Ruel MT. What it takes: evidence from a nutrition- and gender-sensitive agriculture intervention in rural Zambia. J Dev Eff. 2018;10(3):341–72.
10. Lal R. Home gardening and urban agriculture for advancing food and nutritional security in response to the COVID-19 pandemic. Food Sec. 2020;12(4):871–6.
11. Malapit HJL, Sraboni E, Quisumbing AR, Ahmed AU. Intrahousehold empowerment gaps in agriculture and children's well-being in Bangladesh. Deve Policy Rev. 2019;37(2):176–203.
12. Murty PVVS, Rao MV, Bamji MS. Impact of enriching the diet of women and children through health and nutrition education, introduction of homestead gardens and Backyard poultry in rural India. Agric Res. 2016;5(2):210–7.
13. Olney DK, Pedehombga A, Ruel MT, Dillon A. A 2-year integrated agriculture and nutrition and health behavior change communication program targeted to women in Burkina Faso reduces anemia, wasting, and diarrhea in children 3–129 months of age at baseline: a cluster-randomized controlled trial. J Nutr. 2015;145(6):1317–24.
14. Olney DK, Talukder A, Iannotti LL, Ruel MT, Quinn V. Assessing impact and impact pathways of a homestead food production program on household and child nutrition in Cambodia. Food Nutr Bull. 2009;30(4):355–69.
15. Patalagsa MA, Schreinemachers P, Begum S, Begum S. Sowing seeds of empowerment: Effect of women's home garden training in Bangladesh. Agric Food Sec. 2015;4(1):24.
16. Pillai A, Kinabo J, Krawinkel MB. Effect of nutrition education on the knowledge scores of urban households with home gardens in Morogoro, Tanzania. Agric Food Sec. 2016;5(1):22.
17. Schreinemachers P, Baliki G, Shrestha RM, Bhattarai DR, Gautam IP, Ghimire PL, et al. Nudging children toward healthier food choices: An experiment combining school and home gardens. Glob Food Sec. 2020;26:100454. https://doi.org/10.1016/j.gfs.2020.100454.
18. Schreinemachers P, Patalagsa MA, Uddin N. Impact and cost-effectiveness of women's training in home gardening and nutrition in Bangladesh. J Dev Eff. 2016;8(4):473–88.
19. Schreinemachers P, Patalagsa MA, Islam MR, Uddin MN, Ahmad S, Biswas SC, et al. The effect of women's home gardens on vegetable production and consumption in Bangladesh. Food Security. 2015;7(1):97–107.
20. USDA. Nutrient database for standard reference. agriculture research service, united states department of agriculture, Washington, DC. 2015. Available from http://ndb.nal.usda.gov/ndb/search/list (accessed 8 September 2015).
21. van den Bold M, Dillon A, Olney D, Ouedraogo M, Pedehombga A, Quisumbing A. Can integrated agriculture-nutrition programmes change gender norms on land and asset ownership? Evidence from Burkina Faso. J Dev Stud. 2015;51(9):1155–74.
22. Vu L, Rammohan A. Agricultural production diversity and child nutritional outcomes in rural Myanmar. J Dev Stud. 2021. https://doi.org/10.1080/00220388.2021.1983169.
23. Weinberger K. Home and community gardens in Southeast Asia: potential and opportunities for contributing to nutrition-sensitive food systems. Food Sec. 2013;5(6):847–56.
24. Whitney CW, Luedeling E, Hensel O, Tabuti JRS, Krawinkel M, Gebauer J, et al. The role of homegardens for food and nutrition security in Uganda. Hum Ecol. 2018;46(4):497–514.
25. World Vegetable Center. Vegetable Nutrient Database. World Vegetable Center, Shanhua, Taiwan. 2014. Available at: http://nutrition.worldveg.org/
26. Zimpita T, Biggs C, Faber M. Gardening practices in a rural village in South Africa 10 years after completion of a home garden project. Food Nutr Bull. 2015;36:33–42.

Publisher's Note