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CGIAR RESEARCH PROGRAM ON Agriculture for Nutrition and Health
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IFPRI Discussion Paper 02112

April 2022

Increasing Production Diversity and Diet Quality through Agriculture, Gender, and Nutrition Linkages

A Cluster-Randomized Controlled Trial in Bangladesh

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ABSTRACT

A growing body of evidence indicates that agricultural development programs can potentially improve production diversity and diet quality of poor rural households; however, less is known about which aspects of program design are effective in diverse contexts and feasible to implement at scale. We address this issue through an evaluation of the Agriculture, Gender, and Nutrition Linkages (ANGeL) project. ANGeL is a randomized controlled trial testing what combination of trainings focused on agricultural production, nutrition behavior change communication, and gender sensitization were most effective in improving production diversity and diet quality among rural farm households in Bangladesh. We find that trainings focused on agriculture improved production diversity in terms of greater production of fruits and vegetables grown on the homestead, eggs, dairy, and fish; adding trainings on nutrition and gender did not significantly change these impacts. Trainings focused on both agriculture and nutrition showed the largest impacts on diet quality, with evidence indicating that households in this arm also significantly increased consumption out of homestead production for fruits and vegetables, eggs, dairy, and fish. Findings indicate that agricultural training that promotes production of diverse, high-value, nutrient-rich foods can increase production diversity, and this can improve diet quality, but diet quality impacts are larger when agricultural training is combined with nutrition training. Relative to treatments combining agriculture and nutrition training, we find no significant impact of adding the gender sensitization on our measures of production diversity or diet quality.

Keywords: agricultural production, dietary diversity, nutrition-sensitive agriculture, randomized controlled trial, Asia, Bangladesh

ACKNOWLEDGMENTS

We acknowledge funding from the United States Agency for International Development (USAID) through the Policy Research and Strategy Support Program (PRSSP) in Bangladesh under USAID Grant Number EEM-G-00-04-00013-00; the Gender, Agriculture, and Assets Project – Phase 2 (GAAP2), supported by the Bill & Melinda Gates Foundation through INV-008977; the CGIAR Initiative on Transforming Agrifood Systems in South Asia (TAFSSA), and the CGIAR Research Programs on Agriculture for Nutrition and Health (A4NH) and Policies, Institutions, and Markets (PIM). We thank Md. Zahidul Hassan and his colleagues at Data Analysis and Technical Assistance for excellent data collection and Wahid Quabili for exemplary research assistance. We also thank the survey respondents who spent many hours answering questions in the hope of contributing to a better understanding of the intervention. We thank colleagues at the Ministry of Agriculture (MOA) of the Government of Bangladesh and Helen Keller International. We honor the memory of Mr. Toufiqul Alam, former ANGeL Project Director from MOA and Agricultural Policy Support Unit Research Director, who played a key role in successfully implementing ANGeL. The usual disclaimers apply.

ACRONYMS

AEA	Agricultural extension agent
ANCOVA	Analysis of Covariance
ANGeL	Agriculture, Nutrition, and Gender Linkages
BARI	Bangladesh Agricultural Research Institute
BCC	Behavior change communication
BIRTAN	Bangladesh Institute of Research and Training on Applied Nutrition
BRRI	Bangladesh Rice Research Institute
DDS	Diet Diversity Score
FAO	Food and Agriculture Organization
FCS	Food Consumption Score
GDQS	Global Diet Quality Score
hGDQS	Household-level GDQS
HKI	Helen Keller International
IFPRI	International Food Policy Research Institute
IHS	Inverse hyperbolic sine
ITT	Intent-to-treat
LMIC	Low- and middle-income countries
RCT	Randomized controlled trial
SAAO	Sub-assistant agricultural officer
SDI	Simpson (or Herfindahl) Diversification Index
WEAI	Women's Empowerment in Agriculture Index

1. Introduction

Despite substantial improvements in food production and supply in many low- and middle-income countries (LMIC), poor diets remain a persistent challenge. While South Asia, for example, has seen close to a three-fold increase in cereal production over the past four decades (World Bank 2022), diets of many households lack diversity and essential micronutrients, fail to meet or (conversely) exceed caloric requirements, or contain high levels of refined grains and starches (Afshin et al. 2019; FAO 2022; FAO et al. 2021). Micronutrient-rich foods such as vegetables and animal products are more expensive and perishable and less available than staple grains or processed foods in many resource-poor settings (Bai et al. 2021). Accessing a diverse and nutrient-rich diet is therefore challenging for households and communities with limited resources or market access (Bai et al. 2021; Development Initiatives 2020). Consequently, many forms of malnutrition that are partly a result of poor diets are highly prevalent in LMICs. These are reflected in persistently high rates of chronic undernutrition in pre-school children and micronutrient deficiencies in women (World Bank 2022), alongside growing rates of overweight and obesity, particularly in South and South-East Asia (WHO 2017).

These concerns apply to Bangladesh, the focus of this paper. In the early 1970s, Bangladesh was a food-deficit country with a population of about 75 million people (World Bank 2022). Today, the population is 165 million, and the country is now self-sufficient in rice production, which has tripled over the past three decades (World Bank 2022). Seed, fertilizer, and irrigation technologies, known as "Green Revolution technologies," have played major roles in the growth of rice production in Bangladesh (Ahmed et al. 2021). However, there remain considerable shortfalls in the production of certain non-staple crops, such as pulses, vegetables, and fruits – despite these being high-value commodities in terms of marketability (Ahmed and Ghostlaw 2019; FAO 2022). Bangladesh also continues to struggle with deficiencies in micronutrients, such as iron, zinc, iodine, and vitamin A. Such deficiencies reflect poor diets that are rice-dominated, monotonous, and lacking diversity (Ahmed et al. 2013; Ahmed and Ghostlaw 2019).

Enhancing agricultural diversity and production is considered a promising pathway for improving diets and nutrition of rural households. Strong and consistent evidence across LMIC contexts indicates that agricultural development programs that promote the production of diverse, high-value, nutrient-rich food items encourage the production and consumption of these products, and some evidence that programs increase household diet diversity – especially for programs that incorporated a well-implemented nutrition behavior change component (Ruel, Quisumbing and Balagamwala 2018; Gillespie et al. 2019; Bird et al. 2019; Ruel 2019). Women's status and empowerment are also well recognized as being crucial for improving the nutritional impact of agricultural programs (Ruel, Quisumbing, and Balagamwala 2018; Heckert, Olney, and Ruel 2019; Di Prima et al. 2022). Recent evidence from Bangladesh supports the relationships found in the global evidence. Studies indicate that diet quality (dietary diversity in particular) has strong associations with agricultural production diversity, nutrition knowledge, and women's empowerment (Sraboni et al. 2014; Malapit et al. 2018; Kabir et al. 2022). Other work in Bangladesh shows that nutrition behavior change communication (BCC) imparted to women and men in rural households contributes to significant improvements in child nutrition, child development, and complementary feeding practices (Ahmed et al. 2016; Menon et al. 2016; Frongillo et al. 2017; Ahmed et al. 2021). Because the relationships between agricultural diversity, diet diversity, and gender norms are complex and multi-dimensional, it is difficult to tease apart what types of interventions are most important to include (either alone or in combination) to have maximal impact. Furthermore, previous intervention trials have been delivered by non-governmental entities, providing little evidence on the potential for leveraging national agricultural extension platforms to address challenges of production diversity, gender, and diet diversity. Others have delivered BCC alone, without assessing whether emphasis is also needed on strengthening agricultural production or addressing gendered norms within the household.

We address these issues through an evaluation of the impact of the Agriculture, Nutrition, and Gender Linkages (ANGeL) project. ANGeL is a cluster-randomized controlled trial (RCT) implemented by Bangladesh's Ministry of Agriculture. It was designed to test the effects of combinations of nutrition BCC training, agricultural extension, and gender sensitization training focused on intrahousehold relationships, decision-making, and aspects of women's empowerment. We assess ANGeL's implementation fidelity relative to study design, then focus on the intervention's impacts on agricultural knowledge, agricultural production diversity, and diet quality – as well as on interlinkages among these outcomes.[1]

We find that implementation fidelity was high, notable for a government-implemented program undertaken at a relatively large scale across many parts of the country. In terms of intervention impacts, all arms that included nutrition training improved nutrition knowledge. Arms that included nutrition training or agricultural training significantly increased knowledge and adoption of improved agricultural practices; however, arms including agricultural training had significantly larger impacts than those providing nutrition training alone. In terms of increasing production diversity, no treatment arm significantly changed measures based on field crops; however, impacts emerged in terms of homestead gardens and production of eggs, dairy, and fish. At the extensive margin, all arms that included agricultural training led to significant increases in the number of different crops grown in homestead gardens, the likelihood of any egg production, and the likelihood of dairy production; at the intensive margin, arms including agricultural training increased quantities produced of vegetables from the homestead, fruit from the homestead, eggs, dairy products, and fish production. Effects on production diversity tended not to differ significantly between the arm providing agricultural training alone versus the arms that bundled agricultural with nutrition or gender training. In terms of diet quantity as measured by caloric availability, only the treatment arms that included both agricultural and nutrition training had statistically significant impacts, and the magnitudes of these were modest. By contrast, all arms significantly increased a measure of household diet quality (an adaptation of the Global Diet Quality Score (GDQS), a measure designed to be sensitive to multiple forms of malnutrition), and impacts are significantly larger from treatments that combine agricultural training with nutrition training than those providing agricultural training alone. Relative to treatments combining agricultural and nutrition training, we find no significant impact of adding the gender sensitization on our measures of production diversity or diet quality. Our findings indicate that agricultural

[1] We received permission from the Ministry of Agriculture, Government of Bangladesh who issued Letters of Authorization to conduct the surveys described below. The surveys received ethical approval from the Institutional Review Board of IFPRI (IRB approval number 00007490). The study was registered on the Registry for International Development Evaluations (RIDIE-STUDY-ID-5afbe43292b4c).

training promoting the production of diverse, high-value, nutrient-rich food items can increase production diversity, and this alone can improve diet quality; however, impacts on diet quality are larger when agricultural training is combined with nutrition training. We do not assess ANGeL's impacts on decisionmaking and empowerment. A companion paper (Quisumbing et al. 2021), focusing specifically on gender impacts, finds that relative to the control group, all interventions improved women's empowerment without disempowering men.

The paper proceeds as follows. Section 2 describes the interventions implemented for ANGeL, as well as the study design and data collection we used to evaluate these interventions. Section 3 presents our empirical approach. Section 4 documents our findings on implementation fidelity, while Section 5 presents our main findings on ANGeL's impacts on agricultural knowledge, agricultural production diversity, and diet quality. Section 6 discusses implications of these findings and concludes.

2. Interventions, study design, and data collection[2]

2.1 Theory of change for interventions

The premise behind ANGeL's design was that, to improve diets, Bangladesh needs to expand both the production and consumption of non-rice crops. Non-rice food production is understood to affect diets in several ways: through availability, quality, and pricing of these foods; information about the nutritional value of these foods produced; and marketing, including how certain foods are being promoted for sale and consumption. Farm households' production practices can thus improve the diversity, nutrient quality, and quantity of foods available to the household year-round, particularly in environments where markets for certain types of foods (such as perishables) are limited or absent.

The following theory of change guided the design of ANGeL. Along the agricultural production impact pathway, agricultural extension training delivered to men and women provides information on agricultural practices, specifically non-rice crops, livestock, poultry, and fishponds (fish are an important

[2] This section draws on Quisumbing et al. (2021).

protein source in Bangladesh). Adoption of these practices is hypothesized to result in an increased number of non-rice crops and animal-source foods grown, as well as increased productivity in those crops and animal-source foods resulting in greater quantities available for home consumption. On the nutrition impact pathway, delivery of messages on diet quality and nutrition will improve knowledge around healthy diets and consumption of nutrient-rich foods, whether through consumption of own production or through the market. Finally, gender sensitization works along the women's empowerment and decision-making impact pathway, affecting decisions about food choices, allocation of food within the household, and other care practices.

The impacts of these interventions will depend on the fidelity of implementation of interventions and whether interventions succeeded in increasing knowledge. Thus, we look at implementation – in terms of fidelity to providing what was planned and resulting impacts on nutrition knowledge and agricultural knowledge and practices, then their impacts on production diversity and diet diversity. We pay attention to extensive and intensive margins – recognizing that farmers may not completely change cropping patterns, given the large area of land dedicated to rice farming, or fundamentally alter a largely rice-based diet, but may make biologically meaningful changes around the margins.

2.2 Study Design and Intervention Details

As described above, ANGeL aimed to assess interventions that can leverage agricultural growth to increase farm household incomes, improve nutrition, and enhance women's empowerment in Bangladesh. There were three types of training interventions:

1) *Agricultural Production:* Facilitating the production of high-value food commodities that are rich in essential nutrients.
2) *Nutrition Knowledge:* Conducting high-quality BCC to improve nutrition knowledge of women and men.
3) *Gender Sensitization:* Undertaking gender sensitization training that leads to an improvement in the status/empowerment of women and gender parity between women and men.

Accordingly, we implemented a clustered randomized controlled trial with the following arms:[3]

T-A: Agricultural Production training

T-N: Nutrition BCC

T-AN: Agricultural Production training and Nutrition BCC

T-ANG: Agricultural Production training, Nutrition BCC, and Gender Sensitization

C: Control

Training associated with each treatment arm spanned 17 months, from July 2016 (after the baseline survey was completed in January 2016) to December 2017 (before the endline survey commenced in January 2018). Each training session lasted approximately 1.5 hours. In each treatment village, 25 households were invited to attend the trainings. Training took place either in meeting rooms or open courtyards in the villages where study participants resided; approximately 90 percent of participants reported that training sites were within one kilometer of their homes. Trainings took the form of lectures, interactive discussions, practical demonstrations, and question-answer sessions. Both husbands and wives were expected to attend each session, and care was taken to encourage active participation from both men and women. Participants received a small allowance for each training session to cover incidental costs of attending: 125 taka for one participant or 250 taka per household if both the husband and wife participated. The design of each arm is summarized in Appendix Table 1.

The T-N arm consisted of 19 sessions. Topics included an introduction to the functional roles played by different types of foods, the importance of a balanced diet, micronutrients (vitamin A, iron, iodine, and zinc) and sources of food containing these, age-appropriate complementary foods, optimal breastfeeding practices, maternal nutrition and care, safe food preparation and preservation, hygiene, and handwashing. Sessions included lectures, interactive discussions, games, and cooking demonstrations. Helen Keller International (HKI) developed the curriculum and training materials for the nutrition BCC

[3] The RCT included one additional nutrition BCC treatment arm, in which community women delivered the nutrition intervention rather than agricultural extension agents. This arm is not used in this analysis because it was not included in the bundled interventions that we compare to understand additive effects and because it has less practical relevance (the Ministry of Agriculture has planned to use its nationwide agricultural extension workforce to expand ANGeL across the country).

with the Bangladesh Institute of Research and Training on Applied Nutrition (BIRTAN) and IFPRI. Training was delivered by sub-assistant agricultural officers (SAAOs) – also referred to as agricultural extension agents (AEAs) – who are permanent employees of the Bangladesh Ministry of Agriculture.

The T-A arm consisted of 17 sessions. Topics covered an introduction to the cultivation of high-value crops (fruit and vegetables), using crop calendars to design a year-round system of cultivation, preparation of small plots and homestead gardens, water, pest and fertilizer management, harvest techniques, post-harvest storage, and marketing. Raising poultry and small stock (sheep and goats) was also discussed, with attention to breed selection, feeding, vaccination, and diseases. The curriculum also included training on fishpond cultivation; fish is an important protein source in Bangladesh and many Bangladeshi households have small fishponds in their homesteads or cultivate seasonal fishponds (Belton et al. 2011). Although these training sessions focused on agriculture, nutrition content was integrated by building competencies in identifying and cultivating nutrient-dense crops for household consumption and sale. The curriculum and materials for the agricultural production training were developed by HKI in collaboration with the Bangladesh Agricultural Research Institute (BARI) and the Bangladesh Rice Research Institute (BRRI). The 17 sessions included initial training, refresher training on key topics, and opportunities for participants to discuss their experiences applying the training. Training was also delivered by AEAs.

The T-AN arm received the 17 sessions associated with T-N and the 19 sessions associated with T-A. Thus, there were 36 training sessions, led by AEAs.

The T-ANG arm received the 36 sessions associated with T-AN treatment arm, as well as 8 additional sessions on gender sensitization. Topics were based on HKI's *Nurturing Connections* curriculum (Helen Keller International Bangladesh 2016) and facilitated by staff hired by HKI. Sessions included structured activities aimed at improving intra-family respect, appreciation, and communication, as well as improving negotiation skills, to influence women's empowerment. These highly interactive sessions focused on gender relations, power dynamics, communication, and empowerment. The gender sensitization sessions invited mothers-in-law to participate along with husbands and wives, recognizing that they also influence women's empowerment in the context of rural Bangladesh.

2.3 Randomization, Sampling, and Survey Administration

ANGeL's sample was designed to detect impacts of a 10 percent increase in households' per capita daily calorie availability and the Women's Empowerment in Agriculture Index (WEAI) score (Alkire et al. 2013), setting 80 percent power and 0.05 level of significance.[4] Power calculations drew on data from the 2011/2012 round of the Bangladesh Integrated Household Survey, which is nationally representative of rural Bangladesh. The resultant sample size (see below) also provided 80 percent power at 0.05 level of significance to detect an increase of one new food produced in homestead gardens and 7.5 percent increase in household Global Diet Quality Score – measures we use to assess impacts on production diversity and diets.

Because training would be conducted by AEAs, and each AEA was assigned to a "block," it was determined that cluster-randomization would be conducted at the block-level, using blocks as clusters. Working with the Ministry of Agriculture, we identified all rural *upazilas* (sub-districts) that were agro-ecologically suitable for agricultural diversification and had good market connectivity, thus considered appropriate for the ANGeL interventions. From a list of 484 such upazilas, 16 upazilas were purposively selected, such that each of the eight administrative divisions of Bangladesh was represented. From the list of all 525 blocks in 16 upazilas, we randomly selected 10 blocks from each upazila, yielding 160 blocks. Based on the power calculations, these were randomly assigned as follows: 25 blocks to each treatment arm (T-A, T-N, T-AN, T-ANG, as well as the additional treatment described in footnote 3), and 35 blocks to the control group. One village from each block was randomly selected. Within each of these villages, 25 farm households with at least one child under 24 months were randomly selected to participate. This yielded 625 households in each treatment arm (2,500 households in total) and 875 households in the control group, for a total sample of 3,375 households.

[4] The WEAI is a survey-based measure of women's empowerment based on interviews of a primary man and woman in the same household. See Quisumbing et al. (2021) for an analysis of the empowerment impacts of ANGeL.

Baseline data were collected between November 2015 and January 2016. Endline data were collected between January and March 2018, ensuring minimal seasonal difference between baseline and endline surveys. In each household, both the primary female beneficiary and primary male beneficiary were interviewed. Although the male and female beneficiaries were interviewed separately, some modules were answered by only the male (e.g., household demographics, assets and wealth, agricultural production), some were answered by only the female (e.g., food consumption and food security, diet data, women's status, decision-making autonomy) and some were answered separately by each (e.g., data needed to construct measures of empowerment, gender attitudes, time preferences, agency).

2.4 Outcome variables

The logic for our analysis is based on ANGeL's theory of change. ANGeL's agricultural training focused on increasing knowledge around agricultural production beyond growing rice (non-rice field crops, homestead gardening, livestock rearing, poultry raising, fishpond cultivation). If the training increased participants' knowledge, and participants moreover acted on this knowledge by improving agricultural practices, this could improve several dimensions of production. First, agricultural production could diversify. In terms of field crops, this could mean that the household's area of land would be more dispersed over a larger number of different non-rice crops; or it could simply mean that a larger number of different non-rice crops were being cultivated. In terms of homestead gardening, it could mean a larger number of different homestead crops being cultivated. In terms of livestock rearing, poultry raising, or fishpond cultivation, it could mean engagement in each of these activities at all. Second, larger quantities of agricultural output could be produced, consistent with ANGeL's objectives to increase farm incomes. This could correspond to the actual weight produced of non-rice field crops, crops from homestead gardens, milk, eggs, or fish. Third, if some of these were in fact sold, it could translate to higher sales revenue from each type of agricultural output.

ANGeL's nutrition training focused on the importance of diverse diets, including micronutrient-rich foods and animal-source foods. If the training improved knowledge, this could lead to changes in consumption. Linked with the agricultural training, it could moreover lead to increased consumption out of the specific micronutrient-rich or animal-source foods produced: non-rice crops (from the field or homestead), milk, eggs, and fish. In either case, the result could be more a diverse and balanced diet for the household. This could entail consumption of food groups that the household otherwise might not have consumed, or more frequent consumption of certain food groups. It could also increase the actual quantities consumed of various food groups, rebalancing toward those that are micronutrient-rich (e.g., fruits and vegetables) and derived from an animal source (e.g., eggs, milk, fish). Our outcome variables thus trace out this trajectory. We assess measures of agriculture knowledge and practice, agricultural production, and nutrition knowledge and consumption.

2.4.1 Knowledge and practice

To assess whether ANGeL increased nutrition knowledge, we administered questions on optimal feeding practices for children less than 2 years of age, the identification of foods rich in micronutrients such as vitamin A, iron, and zinc, and optimal food preparation practices (e.g., cooking vegetables with oil to improve absorption of fat-soluble vitamins). To assess program impacts on farmer knowledge of improved crop practices, improved livestock and poultry practices, and improved fishpond practices, we administered tests of knowledge to all survey participants at endline. Regarding improved crop practices, a series of questions was asked about preparing pits and beds for vegetable production, as well as about identifying quality seeds and fertilizers, seed storage, and organic methods of controlling pests. Similar questions were asked about the care and feeding of livestock and poultry and about fish culture. Nutrition knowledge and agricultural knowledge questions were asked to participants in all treatment arms and to the control group. Tests were administered separately to male and female respondents. Scores from the 14 questions on nutrition knowledge and 32 questions on crops, livestock, and fish culture were both converted to percent scores.

While improved knowledge is an important first step in efforts to improve production diversity, it has limited benefits if farmers are unwilling or unable to apply this knowledge. At endline, therefore, we asked farmers–men and women separately–about new agricultural, livestock, and fish production practices that they had adopted. We assess whether women or men adopted any new practices, as well as the total number of improved practices that each respondent reported adopting.

2.4.2 Production

We construct several measures of production diversity. When assessing the impact of ANGeL on the diversity of agricultural production, we first construct a measure that accounts for both the number of different crops that the household grows and the intensity, or acreage, devoted to different crops. A measure that allows us to do so is the Simpson (or Herfindahl) Diversification Index (SDI), a measure of diversity used widely to assess production diversity in Bangladesh (Gautam and Faruqee 2016; Rahman 2009). The value of the SDI ranges between zero and one. A value of zero means that the household devotes all its land to one crop. Higher values (values closer to 1) imply greater crop diversity. We also consider measures of field crop production diversity that do not relate to the land area devoted to different crops. These measures are motivated by the fact that, at baseline, a very large fraction (82 percent, on average) of participant households' cropped area was devoted to rice (Ahmed et al. 2018), and households could grow enough non-rice crops to eat substantially more diverse diets without necessarily dramatically changing the acreage devoted to different crops. The second class of measures, frequently found in the literature on production diversity (and its links to consumption diversity), is thus simply the number of different crops that are produced (Sibhatu and Qaim 2018). We examine the impact of ANGeL on the number of non-rice field crops (grown on agricultural fields, not the homestead) and homestead crops (excluding permanent trees). We distinguish between field crops and production on homestead gardens as the latter (homestead vegetable and fruit production to meet micronutrient needs) was encouraged in both the agricultural training and nutrition training. Analogously, we consider measures of whether the household produced any of the animal-source foods emphasized in training: eggs, milk, and fish.

Our next set of production outcomes focuses on the actual quantity produced. We assess the annual quantity produced of non-rice field crops, homestead fruits, homestead vegetables, eggs, dairy, and fish.

Finally, the last set of production outcomes captures the potential for these commodities to generate a marketable surplus: the annual gross sales revenues from each commodity.

2.4.3 Consumption

We assess the impacts of ANGeL on food consumption in two ways. First, the relationship between production of a commodity and its consumption includes several pathways as discussed above, the most direct of which is consumption out of production. Thus, we assess annual homestead vegetable consumption, homestead fruit consumption, and the quantities of egg, dairy, and fish consumed out of production – all in kilograms.

Next, we consider measures of consumption quantity. Using data from a seven-day recall of household food consumption, we calculate per capita caloric availability. Our second measure is an adaptation of a recently developed indicator of diet quality (Bromage et al. 2021), the Global Diet Quality Score (GDQS). [5] The GDQS has several advantages compared to other simple diet-related metrics. Key among these is that, unlike many prior measures of diet quality, GDQS is designed to be sensitive to diet-related outcomes associated with both undernutrition and overnutrition. It includes an expanded set of food groups in comparison to most existing simple food-based metrics such as the Diet Diversity Score (DDS) and the Food Consumption Score (FCS). It also incorporates a measure of quantity of consumption in the metric scoring to allow for a more sensitive assessment of healthy diets. Specifically, it attempts to capture the quantity consumed of different food groups rather than only the numbers of days on which each is consumed. At the same time, the metric is entirely food-based and does not require the use of a food composition table for nutrient analysis.

The GDQS consists of 25 food groups: 16 healthy food groups, seven unhealthy food groups, and two food groups (red meat, high-fat dairy) that are unhealthy when consumed in excessive amounts. For 24

[5] The Global Diet Quality Score (GDQS) research initiative was launched by Intake – Center for Dietary Assessment. The research was led by the Harvard T.H. Chan School of Public Health, Department of Nutrition, and was carried out in collaboration with researchers at the National Public Health Institute (INSP), Mexico.

of the GDQS food groups, three ranges of quantity of consumption are defined (in grams/day) and used in scoring the metric: low, medium, and high. For one food group (high-fat dairy), four ranges of quantity of consumption are used: low, medium, high, and very high. The points associated with the healthy GDQS food groups increase for each higher quantity of consumption category. The points associated with the unhealthy GDQS food groups decrease for each higher quantity of consumption category. For the two food groups that are unhealthy in excessive consumption (red meat, high-fat dairy), the points associated with the GDQS food group increase up to a certain threshold of quantity of consumption, after which the points decrease. The overall GDQS is a sum of the points across all 25 GDQS food groups. The GDQS has a range from 0 to 49.

The definition of GDQS is at the individual-level, wherein each respondent receives points for each GDQS food group, according to the quantity of consumption consumed for that food group during the 24-hour reference period. Although the GDQS was developed after data collection for ANGeL was completed, we compute a version of it using the survey's detailed food consumption module. Because our analysis of ANGeL is at the household-level, and our household-level food consumption data are based on seven-day recall, we construct a variation of the GDQS at the household level, which we refer to as the household-level GDQS (hGDQS). Specifically, we analyze each household's consumption of the various food groups over the seven-day recall, then convert these to a daily adult equivalent.[6]

3. Empirical approach

3.1 Estimation strategy

Our approach to evaluating ANGeL's impacts on knowledge and practices, as well as production and consumption outcomes, takes advantage of the RCT design of the intervention. The randomized assignment of a large sample of eligible households to treatment and control arms helps to reduce the observable and

[6] Because of our adaptation, our household-level calculations of hGDQS may not be directly comparable to the GDQS calculated at the individual-level based on 24-hour recall in other datasets. However, because we construct hGDQS in a consistent manner across all intervention arms in this study, this should not introduce bias for assessing treatment impacts within this study.

unobservable differences across these arms at baseline. We estimate intent-to-treat (ITT) impacts. For all outcomes of interest for which we have baseline values, we use an ANCOVA specification (McKenzie 2012):

$$Y_{ibt} = \alpha_t + \beta_Y Y_{ibt-1} \; \beta_N TN_b + \beta_A TA_b + \beta_{AN} TAN_b + \beta_{ANG} TANG_b + \beta_X X_{ibt-1} + \varepsilon_{ibt} \qquad (1)$$

where Y_{ibt} is the outcome of interest for individual *i* residing in block *b* at time *t*; Y_{ibt-1} is the outcome in the prior period (baseline); TN_b, TA_b, TAN_b, and $TANG_b$ are dummy variables that take the value of 1 if block *b* was assigned to T-N, T-A, T-AN, and T-ANG, respectively, and takes the value of 0 otherwise; X_{ibt-1} is a vector of baseline covariates; and ε_{ibt} is an error term. β_N, β_A, β_{AN}, and β_{ANG} represent the single-difference impact estimator for T-N, T-A, T-AN, and T-ANG, respectively.

Some of our outcomes of interest were collected only at endline (such as knowledge of correct agricultural practices). For these, our estimation relies on single-difference estimates, based on equation (2):

$$Y_{ib} = \alpha + \beta_N TN_b + \beta_A TA_b + \beta_{AN} TAN_b + \beta_{ANG} TANG_b + \beta_X X + \varepsilon_i \qquad (2)$$

All estimation includes the following baseline covariates, intended to capture demographic and socioeconomic characteristics, human capital, land and labor availability, as well as access to information prior to intervention: age of household head, sex of household head, mean education level of males age 18 and older, mean education level of females age 18 and older, number of adults in the household, dependency ratio, wealth index, whether the household had access to electricity, amount of land that was owned at baseline, whether any fishponds were owned at baseline, the number of mobile phones owned, whether the household owned a television, whether the household had recently received an extension visit for crop production, whether the household had recently received an extension visit for livestock or fish production, and dummies for baseline upazila. We also include a dummy variable if the household reported being adversely affected by the widespread flooding that occurred in Bangladesh in the 12-month period prior to the endline survey.

We estimate ordinary-least-squares regressions for outcome variables that are continuous and linear probability models where the outcomes are dichotomous. Count variables, specifically the number of improved agricultural practices adopted, are estimated using Poisson regressions. Our outcome variables relating to levels (in kg) and sales (in taka) of specific types of foods produced and consumed (homestead vegetables, homestead fruits, eggs, dairy, fish) contain both many zero values, as well as many very large values. For these outcomes, we use the inverse hyperbolic sine (IHS) transformation and report marginal effects following Bellemare and Wichman (2020). Our household-level measures of diet, per capita calories and the hGDQS, are log transformed. In all cases, standard errors are clustered at the block-level, which is the level at which the randomization was conducted.

For each outcome, we conduct Wald tests to assess whether the difference in impacts estimated from various treatment arms are statistically significant. Specifically, we assess whether T-N = T-A; T-N = T-AN; T-N = T-ANG; T-A = T-AN; T-A = T-ANG; and T-AN = T-ANG. These comparisons allow us to infer how the single interventions compare, depending on whether they focus on agriculture or nutrition; how combined interventions compare with the single interventions; and how adding gender sensitization to the combined agriculture and nutrition intervention changes impacts.

3.2 Estimation sample, attrition, and baseline descriptives

To develop our estimation sample, we begin with the 3,375 households that comprised the ANGeL sample at baseline.[7] At endline, we successfully re-interviewed 3,289 households that were in the baseline sample. This represents 2.5 percent of the target baseline sample lost to follow up, because: the household migrated (64 households); the household dropped out of the study, declined to be re-interviewed, or could not be

[7] This excludes the households that were randomized into the treatment group that received nutrition training via an NGO.

traced (10 households); or the household was interviewed but the interview was not complete (12 households).

Using a linear probability model, Appendix Table 2 reports how attrition is correlated with treatment arm and baseline covariates. Coefficients on the treatment arms are small in magnitude. There is no statistically significant impact on attrition of the T-N, T-A, or T-ANG treatment arm. Households in the T-AN arm are 1.5 percentage points more likely to attrit than those in the control arm, and this coefficient is significant at the 5 percent level. However, an F test shows that we cannot reject the null hypothesis that, jointly, attrition does not differ across treatment arms; the p-value for this test is 0.19.

With respect to the baseline covariates we consider, attrition increases very slightly with the household dependency ratio and decreases in upazilas where flooding had occurred in the 12-month period prior to the survey. It is slightly higher in the T-AN arm but a joint test of the likelihood of attrition across all treatment arms does not reject the null that they are equal. Attrition is not significantly associated with other selected baseline covariates.

Appendix Table 3 reports the mean values for the baseline covariates selected for inclusion in our regressions. Household heads in the control group are, on average, 40 years old and are overwhelmingly male (3 percent of heads are female). Males age 18 or older have on average, 4.7 years of schooling and females have 5.1 years of schooling. Just over a quarter of control households have a fishpond and they operate 1.07 acres of land. In the 12 months prior to the baseline survey, 19 percent of households had received a visit from an extension officer relating to crop cultivation and 6 percent had received a visit from an extension officer relating to livestock, poultry, or fish production. Magnitudes of baseline covariates are similar across treatment and control arms, although there are small differences. We include baseline covariates in our regressions to help account for these small differences.

4. Implementation fidelity

The ANGeL interventions reported in this paper were conducted primarily by government agents with other responsibilities and were implemented at large scale in many different parts of the country. Despite these challenges, fidelity of implementation to the design was high. Appendix Tables 4-7 describe this in detail; here we highlight key findings.

Attendance at training sessions was high across all treatment arms. The median woman attended 79–94 percent of all the training sessions to which they were invited (with the lowest proportion attended in the T-ANG arm and the highest proportion attended in the T-A arm) (Appendix Table 4). The median man attended 75–94 percent of all the training sessions (again with the lowest proportion attended in the T-ANG arm). Spouses nearly always attended training together; however, some women reported that they could not attend alone if their husband did not attend. The most frequent reason for missing sessions across all arms was non-agricultural work, followed by illness and agricultural work in the fields. If any training sessions were missed, 56–67 percent of participants reported that the SAAO came to them to discuss the material that was missed.

Training sessions were accessible. On average, they were held in a location approximately 0.5 km from participants' homes. One-way travel time to the sessions was around 10–12 minutes and nearly all participants walked. Over 90 percent of participants reported facing no difficulty with travel.

Participants reported valuing the trainings (Appendix Table 5). More than 90 percent of participants said the contents of the training sessions were moderately or very or moderately informative; over 80 percent described the trainers as very communicative, very understandable, and very well prepared (82–88 percent). More than 80 percent of participants reported that they mostly or always understood what was taught, and over 90 percent reported that if they did not understand what was taught, they asked the trainer to repeat, and the trainer did so happily. About 90 percent of participants reported receiving training brochures or posters, and nearly all reported finding these to be helpful.

Both women (Appendix Table 6) and men (Appendix Table 7) overwhelmingly reported that the training was helpful. The value of the trainings was framed both in terms of information learned and in terms of improved confidence, relationships, and social ties. Most women in all arms reported that sessions improved their understanding of care and nutrition of women and children. Women in the T-N arm reported that their children's health improved after the trainings. Women in arms that included an agricultural component stated that they learned new agricultural practices. Following the training, more than 70 percent of women across all arms reported that they gained more respect or status within their homes and communities and that they felt more confident in making decisions about spending money. More than 80 percent of women also reported forming close ties with other participants and meeting with new friends after the training. Men's reports showed similar patterns. Men reported that trainings improved their understanding of care and nutrition of women and children and learned new agricultural practices. More than 60 percent of men reported gaining more respect or status within their homes and communities and feeling more confident in making decisions about spending money. More than 80 percent of men formed close ties with other participants, and more than 78 percent met with new friends after the training. There were however some challenges reported. Between 25–35 percent of women reported that participation in the program interfered with domestic responsibilities as did 51–63 percent of men.

5. Impacts

5.1 Participants' knowledge gained from sessions and translation to practices

Tables 1 and 2 report the impact of the ANGeL treatment arms on knowledge of good nutrition practices, on improved agricultural practices relating to crops, livestock, and fish, and whether these improved practices were adopted. Table 1 reports results for women and Table 2 for men.

For women, all treatment arms that included nutrition training improved nutrition knowledge. The magnitude of the impacts, however, was relatively small, possibly because knowledge was already relatively high, with women in the control group scoring 80 percent on the baseline test (Table 1). The magnitude of the impacts on men's knowledge was slightly higher, possibly because their baseline levels of knowledge were lower (Table 2). All treatment arms increased knowledge of improved agricultural practices. The impacts are always larger for the training arm that included agriculture (T-A, T-AN, T-ANG) than training that only included nutrition knowledge (T-N). Impacts were larger for women than for men, possibly because women attended more training sessions than men. The impacts are large in magnitude.

Table 1: Nutrition knowledge, agriculture knowledge, and adoption of improved agricultural production practices, female

	Control	T-N	T-A	T-AN	T-ANG	T-N = T-A	T-N = T-AN	T-N = T-ANG	T-A = T-AN	T-A = T-ANG	T-AN = T-ANG
	Mean (SE)		*Coefficient (SE)*					*P-value*			
Nutrition knowledge, percent correct	80.1	2.749***	0.625	3.303***	3.055***	<0.01	0.32	0.61	<0.01	<0.01	0.60
	(0.60)	(0.648)	(0.656)	(0.520)	(0.579)						
Agriculture knowledge, percent correct	51.2	5.626***	26.292***	27.501***	26.449***	<0.01	<0.01	<0.01	0.59	0.89	0.66
	(1.32)	(1.311)	(1.255)	(1.324)	(1.414)						
Any adoption, improved agricultural practices	0.26	0.135***	0.577***	0.565***	0.552***	<0.01	<0.01	<0.01	0.74	0.13	0.08
	(0.04)	(0.041)	(0.032)	(0.040)	(0.041)						
			Marginal Effect (SE)								
Number, improved agricultural practices adopted	0.85	1.823**	7.539***	7.778***	7.743***	<0.01	<0.01	<0.01	0.61	0.70	0.90
	(0.16)	(0.69)	(0.99)	(1.13)	(1.12)						

Notes: Nutrition knowledge and agriculture knowledge estimated using OLS. Any adoption is estimated using a linear probability model. Number improved practices adopted estimated using a Poisson estimator. Estimates are intent-to-treat. Standard errors adjusted for clustering at block level are in parentheses. *p<.10; **p<.05; ***p<.01. All specifications include as independent variables the treatment indicators and the following control variables: age and sex of household head, mean education levels of males and females 18 and older, number of adults, dependency ratio, wealth index, land owned at baseline, fishpond owned at baseline, baseline access to information as measured by (baseline) number of mobile phones owned, ownership of television, received extension visit for crop production, received extension visit for livestock or fish production, household has access to electricity, and baseline upazila. Nutrition knowledge also includes baseline percent correct score of nutrition knowledge.

Table 2: Nutrition knowledge, agriculture knowledge, and adoption of improved agricultural production practices, male

	Control Endline	T-N	T-A	T-AN	T-ANG	T-N = T-A	T-N = T-AN	T-N = T-ANG	T-A = T-AN	T-A = T-ANG	T-AN = T-ANG
	Mean (SE)		*Coefficient (SE)*					*P-value*			
Nutrition knowledge, percent correct	71.5	4.714***	3.157***	5.372***	6.142***	0.04	0.42	0.10	<0.01	<0.01	0.39
	(0.8)	(0.74)	(0.66)	(0.77)	(0.81)						
Agriculture knowledge, percent correct	49.8	8.407***	17.877***	17.075***	17.688***	<0.01	<0.01	<0.01	0.36	0.91	0.42
	(1.2)	(1.29)	(1.39)	(1.46)	(1.33)						
Any adoption, improved agricultural practices	0.20	0.260***	0.488***	0.499***	0.434***	<0.01	<0.01	<0.01	0.75	0.49	0.74
	(0.02)	(0.04)	(0.03)	(0.03)	(0.03)						
			Marginal Effect (SE)								
Number, improved agricultural practices adopted	0.708	1.798***	3.850***	3.864***	3.671***	<0.01	<0.01	<0.01	0.91	0.65	0.59
	(0.113)	(0.396)	(0.515)	(0.537)	(0.557)						

Notes: Nutrition knowledge and agriculture knowledge estimated using OLS. Any adoption is estimated using a linear probability model. Number improved practices adopted estimated using a Poisson estimator. Estimates are intent-to-treat. Standard errors adjusted for clustering at block level are in parentheses. *p<.10; **p<.05; ***p<.01. List of control variables is found in Table 1.

For example, relative to the control group, women in the T-AN treatment group scored 27 percentage points higher relative to the control group. Appendix Tables 8 and 9 disaggregate these test scores by subject matter, showing improvements in knowledge of good crop, livestock, and fish culture practices.

Increased knowledge will not translate to changes in outcomes if participants are unable or unwilling to adopt these improved practices. The bottom panels of Tables 1 and 2 show that all treatment arms led to increased adoption of improved agricultural practices. Again, the impacts were always larger for the training arm that included agriculture (T-A, T-AN, T-ANG) than training that only included nutrition knowledge (T-N), and impacts were larger for women than for men. For example, the T-A, T-AN, and T-ANG treatment arms led to an increase of 7.5–7.7 improved agricultural practices by women and 3.6–3.8 improved practices by men. Appendix Tables 8 and 9 show improvements in crop, livestock and fishpond practices by both women and men.

5.2 Production and production diversity

Table 3 considers treatment impacts on the extensive margin of production diversification–assessing whether ANGeL changed an index measuring acreage for various crops, the number of crops grown on fields, the numbers of crops grown in homestead gardens, and whether the household engaged in any egg production, any dairy production, or any fish production. No treatment has any effect on production diversification as measured by the SDI, nor does any arm affect the numbers of crops grown on fields. T-A, T-AN, and T-ANG do increase the number of different crops grown in homestead gardens. However, the effect size is small, around 0.3–0.4 crops, and does not differ across those three arms. Inclusion in the T-A, T-AN, and T-ANG treatment arms increases the likelihood of egg production by 7.210.6 percentage points relative to the control group and we can reject the null that this effect size is equal to the smaller (and non-statistically significant) increase in the likelihood of egg production in T-N, T-A, T-AN, and T-ANG.

Table 3: ANGeL's treatment impacts on measures of production diversity

	Control Baseline	T-N	T-A	T-AN	T-ANG	T-N = T-A	T-N = T-AN	T-N = T-ANG	T-A = T-AN	T-A = T-ANG	T-AN = T-ANG
	Mean (SE)		*Coefficient (SE)*					*P-value*			
Simpson Diversification Index	0.20	0.008	0.002	-0.003	-0.006	0.73	0.60	0.52	0.80	0.72	0.88
	(0.02)	(0.018)	(0.013)	(0.016)	(0.019)						
Number, non-rice field crops	0.68	0.043	0.012	0.014	0.093	0.69	0.75	0.64	0.98	0.46	0.50
	(0.09)	(0.078)	(0.062)	(0.081)	(0.109)						
Number, homestead crops	1.35	-0.052	0.382***	0.356***	0.311***	<0.01	0.04	0.03	0.86	0.56	0.74
	(0.15)	(0.138)	(0.099)	(0.127)	(0.103)						
Any egg production	0.76	0.023	0.106***	0.072***	0.089***	<0.01	0.10	0.03	0.14	0.50	0.51
	(0.02)	(0.028)	(0.022)	(0.024)	(0.026)						
Any dairy production	0.32	0.020	0.041*	0.064**	0.066***	0.33	0.13	0.04	0.44	0.31	0.95
	(0.03)	(0.02)	(0.022)	(0.031)	(0.025)						
Any fish production	0.58	-0.005	0.024	0.044*	0.028	0.30	0.10	0.32	0.41	0.86	0.61
	(0.04)	(0.029)	(0.023)	(0.027)	(0.029)						

Note: Estimates are intent-to-treat. Where statistically significant at $p < 0.10$, marginal effects (ME) are reported using the method found in Bellemare and Wichman (2020). Standard errors adjusted for clustering at block level are in parentheses. *p<.10; **p<.05; ***p<.01. All specifications include as independent variables the treatment indicators, baseline values of the outcome variables and the control variables listed in the notes to Table 1.

increase the likelihood of both the production of dairy products by 4.1–6.6 percentage points; the impact on fish production of these treatment arms is smaller and only for T-AN is it (marginally) statistically significant.

However, much of the agricultural training was around increasing productivity, not merely increasing the number of different crops grown (e.g., this included training around how to select seeds, reduce pest infestation etc.). Thus, we next look at the intensive margin of production diversification, assessing whether the quantities of various types of agricultural production changed due to treatment. We do so in Tables 4 (homestead garden production of vegetables and fruit) and 5 (animal-source foods: eggs, dairy, and fish).

Table 4 shows that all treatment arms that included agricultural training increased homestead production of vegetables and fruit relative to the control group. The magnitudes of these effect sizes are large, ranging from 21 (impact of T-ANG on vegetable production) to 29 (impact of T-ANG on fruit production). We can reject the null hypothesis that these impacts are equal to the (non-statistically significant) effects of the nutrition training alone. Using the impacts of T-AN as an example, ANGeL increased annual homestead garden production of vegetables (relative to the baseline control mean) by 9.4 kg and increased annual homestead garden production of fruit by 48.3 kg. The impacts of T-AN and T-ANG are very close in magnitude, and we cannot reject the null that they are equal.

Table 5 shows that all treatment arms that included agricultural training (T-A, T-AN, T-ANG) increased the production of eggs and dairy products, and T-A and T-AN increased fish production (the impact estimate for T-ANG lies just outside the 10 percent significance level). The effect sizes are large: 58–88 percent increases for eggs; 27–48 percent for dairy; and 22–26 percent increases for fish production. Note that the smaller impacts of fish production are consistent with the smaller impacts on adoption of improved fishpond practices described above. Using the impacts of T-AN as an example, ANGeL increased annual egg production (relative to the baseline control mean) by 40 eggs, increased annual dairy production by 37 liters, and annual fish production by 39.5 kg. Again, the impacts of T-AN and T-ANG are very close in magnitude, and we cannot reject the null that they are equal.

Table 4: ANGeL's treatment impacts on production quantity from homestead gardens

	Control Baseline	T-N	T-A	T-AN	T-ANG	T-N = T-A	T-N = T-AN	T-N = T-ANG	T-A = T-AN	T-A = T-ANG	T-AN = T-ANG
	Mean (SE)	*Coefficient (SE) [ME]*				*P-value*					
Homestead garden vegetable production, kg (IHS)	37.5	-0.054	0.203*	0.223*	0.187*	0.05	0.07	0.07	0.88	0.90	0.77
	(5.7)	(0.114)	(0.105)	(0.115)	(0.109)						
			[0.22]	[0.25]	[0.21]						
Homestead garden fruit production, kg (IHS)	172.4	-0.057	0.226	0.247*	0.257*	0.06	0.04	0.02	0.90	0.84	0.95
	(26.5)	(0.127)	(0.137)	(0.129)	(0.133)						
				[0.28]	[0.29]						

Note: Estimates are intent-to-treat. Where statistically significant at $p < 0.10$, marginal effects (ME) are reported using the method found in Bellemare and Wichman (2020). Standard errors adjusted for clustering at block level are in parentheses. *p<.10; **p<.05; ***p<.01. All specifications include as independent variables the treatment indicators, baseline values of the outcome variables and the control variables listed in the notes to Table 1.

Table 5: ANGeL's treatment impacts on production quantity and sales revenue of animal-source foods

	Control Baseline	T-N	T-A	T-AN	T-ANG	T-N = T-A	T-N = T-AN	T-N = T-ANG	T-A = T-AN	T-A = T-ANG	T-AN = T-ANG
	Mean (SE)		*Coefficient (SE) [ME]*					*P-value*			
Egg production (IHS)	69.7	0.084	0.635***	0.459***	0.582***	<0.01	0.01	0.01	0.14	0.68	0.37
	(6.6)	(0.138)	(0.116)	(0.123)	(0.136)						
			[0.88]	[0.58]	[0.79]						
Dairy production (IHS)	78.5	0.114	0.242*	0.391**	0.356**	0.31	0.11	0.06	0.41	0.43	0.85
	(14.3)	(0.116)	(0.13)	(0.18)	(0.14						
			[0.27]	[0.48]	[0.43]						
Fish production (IHS)	179.8	0.097	0.231**	0.197**	0.185	0.22	0.34	0.50	0.71	0.71	0.92
	(78.5)	(0.113)	(0.099)	(0.092)	(0.117)						
			[0.26]	[0.22]							
Egg gross sales revenues (IHS)	62.5	0.049	0.323**	0.147	0.298**	0.02	0.42	0.08	0.16	0.87	0.27
	(22.4)	(0.108)	(0.124	(0.118)	(0.131						
			[0.38]		[0.35]						
Dairy gross sales revenues (IHS)	1666.9	0.003	0.049	0.256	0.082	0.77	0.24	0.67	0.32	0.86	0.45
	(495.1)	(0.164)	(0.153)	(0.21)	(0.193)						
Fish gross sales revenues (IHS)	8436	0.191	0.315*	-0.071	0.071	0.48	0.10	0.47	0.02	0.16	0.32
	(3708)	(0.161)	(0.165)	(0.152)	(0.148)						
			[0.37]								

Note: Estimates are intent-to-treat. Where statistically significant at $p < 0.10$, marginal effects (ME) are reported using the method found in Bellemare and Wichman (2020). Standard errors adjusted for clustering at block level are in parentheses. *p<.10; **p<.05; ***p<.01. All specifications include as independent variables the treatment indicators, baseline values of the outcome variables and the control variables listed in the notes to Table 1. IHS=inverse hyperbolic sine.

We next consider impacts on sales revenue from these commodities. The bottom panel of Table 5 shows that, while there is some evidence of ANGeL participants selling some of their increased production, it is not consistent across treatment arms; moreover, the percentage changes where the impact coefficients are significant are smaller than those seen for production. This suggests that households are consuming this increased production, a point we discuss below.

To summarize, all treatment arms that included agricultural training (T-A, T-AN, and T-ANG) had small effects on measures of production at the extensive margin. They had much larger effects on measures of production at the intensive margin.

5.3 Consumption

We begin by assessing the extent to which study participants consumed the increased production of homestead vegetables, homestead fruit, and animal-source foods. Table 6 indicates that this was common. In nearly all food products considered, inclusion in the T-A, T-AN, or T-ANG treatment arms resulted in a statistically significant increase in consumption (and in the few cases where they are not significant, the impacts lie just outside the 10 percent significance level). The magnitudes of these effect sizes are large, ranging from 19 percent (impact of T-A on vegetable consumption) to 81 percent (impact of T-A on egg production). Using the impacts of T-AN as an example, ANGeL increased (relative to the baseline control mean) annual consumption of vegetables produced on homestead gardens by 5.3 kg, fruit consumption by 22.2 kg, egg consumption by 25.6 eggs, dairy consumption by 17.4 liters, and fish consumption by 19.0 kg.

We now turn to our two measures of diet, caloric availability (a quantity measure) and the hGDQS (a quality measure). Table 7 shows that only the treatment arms that included both agricultural and nutrition training had statistically significant impacts, and the magnitudes of these were modest. By contrast, when we use log hGDQS, all treatments have a significant effect for all treatment arms. They are largest (around 10 percent) for T-AN and T-ANG. For hGDQS, we can reject the null that T-A = T-AN and T-A = T-ANG. Once again, the impacts of T-AN and T-ANG are very close in magnitude, and we cannot reject the null

Table 6: ANGeL's treatment impacts on food consumption out of selected own production activities

	Control Baseline	T-N	T-A	T-AN	T-ANG	T-N = T-A	T-N = T-AN	T-N = T-ANG	T-A = T-AN	T-A = T-ANG	T-AN = T-ANG
	Mean (SE)		*Coefficient (SE) [ME]*					*P-value*			
Homestead garden vegetable consumption, kg (IHS)	24.2	-0.056	0.171*	0.196*	0.150	0.07	0.07	0.10	0.84	0.86	0.68
	(3.6)	(0.104)	(0.099)	(0.105)	(0.100)						
			[0.19]	[0.22]							
Homestead garden fruit consumption, kg (IHS)	101.1	-0.03	0.195	0.203*	0.227**	0.08	0.06	0.03	0.95	0.81	0.83
	(10.1)	(0.11)	(0.118)	(0.108)	(0.113)						
				[0.22]	[0.22]						
Egg consumption (IHS)	45.0	0.12	0.593***	0.451***	0.529***	0.01	0.01	0.04	0.20	0.60	0.55
	(4.1)	(0.124)	(0.105	(0.114)	(0.129)						
			[0.809]	[0.570]	[0.697]						
Dairy consumption (IHS)	37.8	0.125	0.251**	0.378**	0.349***	0.29	0.10	0.06	0.42	0.45	0.85
	(4.3)	(0.104)	(0.11)	(0.16)	(0.12)						
			[0.29]	[0.46]	[0.42]						
Fish consumption (IHS)	94.9	0.052	0.174*	0.186**	0.169	0.25	0.22	0.36	0.89	0.96	0.87
	(69.2)	(0.109)	(0.09)	(0.088)	(0.110)						
			[0.19]	[0.20]							

Note: Estimates are intent-to-treat. Where statistically significant at p < 0.10, marginal effects (ME) are reported using the method found in Bellemare and Wichman (2020). Standard errors adjusted for clustering at block level are in parentheses. *p<.10; **p<.05; ***p<.01. All specifications include as independent variables the treatment indicators, baseline values of the outcome variables and the control variables listed in the notes to Table 1. IHS=inverse hyperbolic sine.

Table 7: ANGeL's treatment impacts on measures of consumption diversity

	Control Baseline	T-N	T-A	T-AN	T-ANG	T-N = T-A	T-N = T-AN	T-N = T-ANG	T-A = T-AN	T-A = T-ANG	T-AN = T-ANG
	Mean (SE)	*Coefficient (Standard Error) [Marginal Effect]*						*P-value*			
Log calories per capita	1982.6	0.032	0.007	0.040**	0.059***	0.20	0.69	0.22	0.09	0.01	0.32
	(32.3)	(0.017)	(0.016)	(0.016)	(0.018)						
		[0.033]	[0.007]	[0.040]	[0.060]						
Log hGDQS	18.1	0.069***	0.066***	0.098***	0.091***	0.84	0.14	0.23	0.05	0.12	0.69
	0.13	(0.019)	(0.016)	(0.015)	(0.015)						
		[0.072]	[0.068]	[0.103]	[0.095]						

Note: Estimates are intent-to-treat. Where statistically significant at $p < 0.10$, marginal effects (ME) are reported using the method found in Bellemare and Wichman (2020). Standard errors adjusted for clustering at block level are in parentheses. *p<.10; **p<.05; ***p<.01. Both specifications include as independent variables the treatment indicators, baseline values, and the control variables listed in the notes to Table 1. hGDQS=household-level global diet quality score.

that they are equal. In other words, the addition of nutrition training to agricultural training significantly increases the impact on this diet measure, relative to agricultural training alone. By contrast, the addition of the gender sensitization training has no additional impact on consumption relative to that generated by the agriculture and nutrition training.

In Appendix Table 10, we report impacts on two other commonly used food security measures: the DDS (a count variable based on whether the household consumed different food groups and with a range from zero to 12; see Leroy et al. (2015); and FCS (World Food Program 2008)). The FCS combines information on the frequency of consumption of different food groups in the past seven days, weighting each food group differently and ranging in value from 0 to 117. These show that the effects of T-N and T-A tend to be smaller than T-AN and T-ANG and are not always statistically significant. The difference between the FCS and the hGDQS results suggests that ANGeL shows impacts in ways not captured by the FCS; specifically, households in the T-AN and T-ANG arms may be consuming larger quantities of non-rice foods–not just consuming a food from those food groups on more days–consistent with the above results on consumption out of own production. Further, the increases in hGDQS are more likely to be capturing an improvement in household-level diets, since for example sugars are not weighted positively in the hGDQS as they are in FCS.

6. Conclusion

ANGeL was designed to test whether trainings in agricultural production practices, nutrition BCC, and gender sensitization, delivered together to husbands and wives, could improve production diversity and diet quality in rural Bangladesh, and whether these components worked better as independent treatments or as bundled treatments. The intervention was implemented well; implementation fidelity was high, and respondents indicated that they were satisfied with the content and quality of the training. High implementation fidelity is reflected in increased knowledge of improved agricultural practices, across treatment arms, with quantitatively larger impacts for the training arm that included agriculture (T-A, T-AN, T-ANG) than training that only included nutrition knowledge (T-N). Impacts were larger for women than for men. This improved agricultural knowledge translated into higher adoption of improved agricultural practices across all treatment arms, again with larger impacts for the treatment arm including agriculture training. Impacts were also larger for women than for men.

Agricultural production training treatments (T-A, T-AN, and T-ANG) had small effects on measures at the extensive margin. No treatment had any effect on production diversification as measured by the SDI based on field crops or the absolute number of crops grown on fields. These limited impacts on production diversity in terms of field crops may reflect a combination of a reluctance of farmers to switch field acreage out of rice together with only limited space for homestead gardens. Treatment arms with agricultural training did increase the number of different crops grown in homestead gardens, albeit with small effect sizes. Agricultural production training treatments (T-A, T-AN, and T-ANG) also significantly increased the likelihood of any egg production or any dairy production; the impact on the likelihood of any fish production is smaller and marginally significant only for T-AN.

The treatments had much larger effects on measures of production at the intensive margin. All treatment arms that included agricultural training increased the production of vegetables and fruit relative to the control group. Similarly, all treatment arms that included agricultural training increased the production quantity of eggs and dairy products, and T-A and T-AN increased fish production with large effect sizes. However, these effects do not differ across T-A, T-AN, and T-ANG, suggesting that the bundled treatments did not have any additive impacts relative to the agricultural production training delivered alone. Moreover, impacts on sales revenue tend not to be significant for most of the commodities, other than T-ANG and T-A causing small but significant increases in sales of eggs.

We also see households consuming much of this additional production, but again with no significant differences across T-A, T-AN, and T-ANG. We see improvements in household-level diet, both quantity and quality, but these are more apparent when we focus on diet quality. Further, we see for consumption that T-AN and T-ANG have larger effects than T-A alone, suggesting that for T-A, increased consumption out of own production is somewhat offset by reductions in consumption from other sources, whereas T-AN and T-ANG result in less crowding out of consumption from non-homestead garden sources.

This could reflect the content of the treatment arms with nutrition BCC, which encouraged the consumption of nutrient-rich foods such as fruits, vegetables, and animal-source foods.

Another objective of ANGeL was to test whether bundled interventions worked better than single interventions. It appears that the improvements in agricultural production—observed mainly in the intensive margin—came only from the treatment arms that included agricultural production training. It also appears that improvements in diet quality come from treatment arms with the agricultural training, although the nutrition training may have had an additive effect, based on our hGQDS measure. Interestingly, the gender sensitization arm does not appear to convey additional benefits in terms of gains in agricultural production diversity and consumption diversity. This result is similar to the estimated impacts on women's empowerment in a companion paper (Quisumbing et al. 2021). Quisumbing et al. (2021) found that, while the gender sensitization arm reported larger impacts on some measures of women's empowerment, these were not statistically different from other treatment arms. The lack of a differential impact of the gender sensitization arm and the absence of a detectable difference across arms could arise from all implementation modalities providing information to both husbands and wives when they were together, or from the relatively low number of sessions focused on gender sensitization compared to the number of sessions focused on nutrition training or agricultural production training.

We end by noting that a striking feature of ANGeL was the use of government extension agents to deliver both nutrition and agriculture training to both men and women. This suggests that scaling up ANGeL would be feasible in Bangladesh. Moreover, by demonstrating that agricultural extension agents, not health workers, were able to effectively provide integrated agriculture and nutrition training at a relatively large scale, ANGeL offers a model for other settings where shifting agricultural production is key to achieving diet goals.

REFERENCES

Afshin A., P.J. Sur, K.A. Fay, L. Cornaby, G. Ferrara, J.S. Salama, E.C. Mullany, K.H. Abate, C. Abbafati, and Z. Abebe et al. 2019. "Health effects of dietary risks in 195 countries, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017." *The Lancet* 393(10184):1958-1972. Available at: http://www.thelancet.com/article/S0140673619300418/fulltext [Accessed March 18, 2022].

Ahmed, A.U., K. Ahmad, V. Chou, R. Hernandez, P. Menon, F. Naeem, W. Quabili, E. Sraboni, and B. Yu. 2013. The Status of Food Security in the Feed the Future Zone and Other Regions of Bangladesh: Results from the 2011-2012 Bangladesh Integrated household Survey. Project Report prepared for the U.S. Agency for International Development (USAID). Dhaka: International Food Policy Research Institute. http://thedata.harvard.edu/dvn/dv/IFPRI/faces/study/StudyPage.xhtml?globalId=hdl:1902.1/21266

Ahmed, A.U., and J. Ghostlaw. 2019. Diversifying rice-centric agriculture and diets: The Bangladesh experience. In *Agriculture for improved nutrition: Seizing the momentum*. Chapter 15. Fan, S. , S. Yosef R. Pandya-Lorch (Eds.). Wallingford, UK: International Food Policy Research Institute (IFPRI) and CABI. http://ebrary.ifpri.org/cdm/ref/collection/p15738coll2/id/133088

Ahmed A.U., J. Hoddinott, P. Menon, A.R. Quisumbing, S. Roy, and M. Younus. 2018. *Agriculture, Nutrition, and Gender Linkages (ANGeL): Evaluation Results*. International Food Policy Research Institute: Dhaka, Bangladesh.

Ahmed, A.U., J. Hoddinott, S. Roy, E. Sraboni, W. Quabili, and A. Margolies. 2016. *Which Kinds of Social Safety Net Transfers Work Best for the Ultra Poor in Bangladesh? Operation and Impacts of the Transfer Modality Research Initiative*. Project report. Dhaka: International Food Policy Research Institute.

Ahmed, A.U., N. Islam, and M.K. Mujeri. 2021. "Introduction." In *Securing Food for All in Bangladesh*. Ahmed, A.U., N. Islam, and M. K. Mujeri (Eds.). Dhaka, Bangladesh: University Press Limited. https://ebrary.ifpri.org/utils/getfile/collection/p15738coll2/id/134738/filename/134949.pdf

Alkire, S., R. Meinzen-Dick, A. Peterman, A. Quisumbing, G. Seymour, and A. Vaz. 2013. "The Women's Empowerment in Agriculture Index." *World Development* 52: 71-91, ISSN 0305-750X, https://doi.org/10.1016/j.worlddev.2013.06.007.

Bai, Y., R. Alemu, S.A. Block, D. Headey, and W.A. Masters. 2021. "Cost and affordability of nutritious diets at retail prices: Evidence from 177 countries." *Food Policy* 99:101983.

Belton, B., M. Karim, S. Thilsted, K. Murshed-E-Jahan, W. Collis, and M. Phillips. 2011. *Review of aquaculture and fish consumption in Bangladesh*. The World Fish Center.

Bellemare, M.F., and C.J. Wichman. 2020. "Elasticities and the Inverse Hyperbolic Sine Transformation." *Oxford Bulletin of Economics and Statistics* 82(1): 50-61.

Bird, F.A., A. Pradhan, R. v. Bhavani, and A.D. Dangour. 2019. "Interventions in agriculture for nutrition outcomes: A systematic review focused on South Asia." *Food Policy* 82:39–49.

Bromage S., C. Batis, S.N. Bhupathiraju, W.W. Fawzi, T.T. Fung, Y. Li, M. Deitchler, E. Angulo, N. Birk, A. Castellanos-Gutiérrez, Y. He, Y. Fang, M. Matsuzaki, Y. Zhang, M. Moursi, S. Gicevic, M.D. Holmes, S. Isanaka, S. Kinra, S.E. Sachs, M.J. Stampfer, D. Stern, and W.C. Willett. 2021. "Development and Validation of a Novel Food-Based Global Diet Quality Score (GDQS)." *The Journal of Nutrition* 151(12 Suppl 2):75S-92S. doi: 10.1093/jn/nxab244. PMID: 34689200; PMCID: PMC8542096.

Development Initiatives. 2020. "Food systems and nutrition equity." In *2020 Global Nutrition Report: Action on equity to end malnutrition*. Chapter 3. Bristol, UK: Development Initiatives Poverty Research Ltd.

Di Prima, S., E. Wright, I. Sharma, E. Syurina, and J. Broerse. 2022. "Implementation and scale-up of nutrition-sensitive agriculture in low- and middle-income countries: a systematic review of what works, what doesn't work and why." *Global Food Security* 32:e100595.

FAO, UNICEF, WFP, and WHO. 2021. "Asia and the Pacific Regional Overview of Food Security and Nutrition 2020: Maternal and child diets at the heart of improving nutrition." Bangkok, FAO. https://doi.org/10.4060/cb2895en

FAO. 2022. FAOSTAT Statistical Database: Food Balances. Available at: https://www.fao.org/faostat/en/#data/FBS/report [Accessed March 18, 2022].

Frongillo, E., P. Nguyen, S. Kuntal, S. Tina, K. Afsana, H. Raisul, J. Baker, M.T. Ruel, R. Rawat, P. Menon. 2017. "Large-Scale Behavior-Change Initiative for Infant and Young Child Feeding Advanced Language and Motor Development in a Cluster-Randomized Program Evaluation in Bangladesh." *The Journal of Nutrition.* 147(2): 256-263. https://doi.org/10.3945/jn.116.240861

Gautam, M., and R. Faruqee. 2016. *Dynamics of Rural Growth in Bangladesh: Sustaining Poverty Reduction. Directions in Development*. Washington, DC: World Bank. doi:10.1596/978-1-4648-0876-0.

Gillespie, S., N. Poole, M. van den Bold, R. v. Bhavani, A.D. Dangour, and P. Shetty. 2019. "Leveraging agriculture for nutrition in South Asia: What do we know, and what have we learned?" *Food Policy* 82: 3-12.

Heckert, J., D.K. Olney, and M.T. Ruel. 2019. "Is women's empowerment a pathway to improving child nutrition outcomes in a nutrition-sensitive agriculture program? Evidence from a randomized controlled trial in Burkina Faso." *Social Science and Medicine* 233: 93-102.

Helen Keller International Bangladesh. 2016. ANGeL Course Content for Homestead Food Production and High Value Crops.

Leroy, J., M.T. Ruel, E. Frongillo, J. Harris, and T. Ballard. 2015. "Measuring the food access dimension of food security: A critical review and mapping of indicators." *Food and Nutrition Bulletin* 36(2): 167-195.

Kabir, M.R., O. Halima, N. Rahman, S. Ghosh, Md. S. Islam, and H. Rahman. 2022. "Linking farm production diversity to household dietary diversity controlling market access and agricultural technology usage: evidence from Noakhali district, Bangladesh." *Heliyon* 8(1): e08755.

Malapit, H.J., E. Sraboni, A.R. Quisumbing, and A.U. Ahmed. 2018. "Intrahousehold empowerment gaps in agriculture and children's well-being in Bangladesh." *Development Policy Review.* https://doi: 10.1111/dpr.12374

Menon, P., P.H. Nguyen, K. K. Saha, A. Khaled, T. Sanghvi, J. Baker, K. Afsana, R. Haque, E.A. Frongillo, M.T. Ruel, and R. Rawat. 2016. "Combining Intensive Counseling by Frontline Workers with a Nationwide Mass Media Campaign Has Large Differential Impacts on Complementary Feeding Practices but Not on Child Growth: Results of a Cluster-Randomized Program Evaluation in Bangladesh." *The Journal of Nutrition*. doi: 10.3945/jn.116.232314

McKenzie, D. 2012. "Beyond baseline and follow-up: The case for more T in experiments." *Journal of Development Economics* 99(2): 210-221. https://doi.org/10.1016/j.jdeveco.2012.01.002.

Quisumbing A.R., A.U. Ahmed, J. Hoddinott, A. Pereira, and S. Roy. 2021. "Designing for empowerment impact in agricultural development projects: Experimental evidence from the Agriculture, Nutrition, and Gender Linkages (ANGeL) project in Bangladesh." *World Development* 146.

Rahman, S. 2009. "Whether crop diversification is a desired strategy for agricultural growth in Bangladesh?" *Food Policy* 34(4): 340-349.

Ruel, M.T. 2019. "New evidence on nutrition-sensitive agricultural programs." In *Agriculture for improved nutrition: Seizing the momentum*. Chapter 9. Fan, S.. S. Yosef, R. Pandya-Lorch (Eds.). Wallingford, UK: International Food Policy Research Institute (IFPRI) and CABI. http://ebrary.ifpri.org/cdm/ref/collection/p15738coll2/id/133086

Ruel, M.T., A.R. Quisumbing, and M. Balagamwala. 2018. "Nutrition-sensitive agriculture: What have we learned so far?" *Global Food Security* 17: 128-153.

Sibhatu, K., and M. Qaim. 2018. “Review: Meta-analysis of the association between production diversity, diets, and nutrition in smallholder farm households.” *Food Policy* 77: 1-18.

Sraboni, E., H.J. Malapit, A.R. Quisumbing, and A.U. Ahmed. 2014. “Women’s Empowerment in Agriculture: What Role for Food Security in Bangladesh?” *World Development* 61: 11-52.

World Food Program. 2008. Food Consumption Analysis: Calculation and Use of the Food Consumption Score in Food Security Analysis. Rome.

WHO (World Health Organization). 2017. Global Health Observatory data repository: Prevalence of Overweight, Prevalence of Obesity. Available at: https://apps.who.int/gho/data [Accessed December 20, 2021].

World Bank. 2022. World Development Indicators Available at: https://data.worldbank.org [Accessed March 19, 2022].

APPENDIX

Online Supplementary Materials

Appendix Table 1. Summary of ANGeL intervention components

	Agriculture training (A)	Nutrition training (N)	Gender training (G)
Length of training period	17 months	17 months	17 months
Number of sessions	17	19	8
Topics covered	▪ cultivation of high value crops (fruit and vegetables) ▪ using crop calendars to design a year-round cultivation system ▪ preparation of small plots and vegetable gardens water, pest, and fertilizer management ▪ harvest techniques ▪ post-harvest storage and marketing ▪ raising poultry and small livestock (sheep and goats) ▪ animal breed selection, feeding, vaccination, and diseases ▪ fishpond cultivation	▪ the importance of a balanced diet, micronutrients (vitamin A, iron, iodine, and zinc) and sources of food containing these ▪ age-appropriate complementary foods ▪ optimal breastfeeding practices ▪ maternal nutrition and care ▪ safe food preparation and preservation, hygiene, and handwashing	▪ building trust ▪ listening and communication skills ▪ gendered perspectives ▪ power relations and negotiation ▪ shared decision-making and assertiveness
Training format	Introductory lectures, practical demonstrations, and interactive question and answer sessions	Lectures, interactive discussions, games, and cooking demonstrations	Interactive activities, games, and group/pair discussions
Trainers	Agricultural extension agents from Bangladesh Ministry of Agriculture	Agricultural extension agents from Bangladesh Ministry of Agriculture	Women and men from the community hired and trained by Helen Keller International
Who was invited to attend	Husbands and wives	Husbands and wives	Husbands and wives and mothers-in-law

Appendix Table 2: Correlates of Attrition

	Coefficient	Standard Error
T – N	0.009	0.009
T – A	-0.001	0.009
T – AN	0.015**	0.007
T – ANG	0.004	0.011
Baseline characteristics		
Age, household head (years)	0.000	0.000
Female headed household	0.000	0.017
Average years of education of male (18+)	0.001	0.001
Average years of education of female (18+)	-0.001	0.001
Number of adults (>=18 years)	0.002	0.003
Dependency ratio (# dependents/# working people)	0.011***	0.004
Consumer durable wealth index	0.001	0.002
Has a cultivable pond suitable for fish	0.005	0.008
Land operated (acres)	-0.000	0.002
Number of working mobile phones	-0.000	0.003
Has electricity connection	0.010	0.009
Owns television	-0.011	0.007
Had received visit from extension officer relating to crop cultivation in 12 months prior to interview	0.006	0.006
Had received visit from extension officer relating to livestock, poultry, or fish production in 12 months prior to interview	0.016	0.012
Shocks between baseline and endline		
Upazila experienced flooding in last 12 months	-0.091***	0.027
Constant	1.016***	0.035
Upazila fixed effects	YES	
Number of Observations	3,375	
Tests of joint significance		
F statistic: Treatment arms	1.57	
p-value	0.19	

Note: Linear probability model where dependent variable equals one if household attrited. Standard errors adjusted for clustering at block level. *p<.10; **p<.05; ***p<.01.

Appendix Table 3: Mean values of baseline covariates, by treatment arm

	T – N		T – A		T – AN		T – ANG		Control	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Age, household head (years)	40.15	14.00	40.49	13.55	41.40	14.27	40.94	13.77	41.17	13.87
Female headed household	0.04	0.19	0.04	0.19	0.04	0.20	0.05	0.22	0.03	0.18
Average years of education of male (18+)	4.87	3.65	4.58	4.04	4.13	3.68	4.70	3.59	4.72	3.89
Average years of education of female (18+)	5.16	2.73	5.34	2.99	4.52	2.75	5.15	2.71	5.16	2.90
Number of adults (>=18 years)	3.27	1.61	3.06	1.39	3.23	1.54	3.13	1.40	3.17	1.43
Dependency ratio (# dependents/# working people)	0.96	0.63	0.96	0.60	1.03	0.65	0.96	0.58	1.00	0.62
Consumer durable wealth index	-0.04	2.64	0.32	2.48	-0.03	2.51	-0.08	2.36	0.23	2.51
Has a cultivable pond suitable for fish	0.24	0.43	0.28	0.45	0.21	0.41	0.19	0.40	0.27	0.45
Land operated (acres)	1.18	1.29	1.12	1.22	1.08	1.17	0.93	0.79	1.07	1.08
Number working mobile phones	1.77	1.27	1.64	1.11	1.74	1.22	1.68	1.14	1.62	1.22
Owns television	0.36	0.48	0.34	0.47	0.33	0.47	0.32	0.46	0.36	0.48
Received visit from extension officer relating to crop cultivation in 12 months prior to interview	0.21	0.41	0.24	0.43	0.22	0.42	0.19	0.39	0.19	0.40
Received visit from extension officer relating to livestock, poultry, or fish production in 12 months prior to interview	0.03	0.16	0.06	0.24	0.04	0.20	0.02	0.15	0.06	0.24
Has electricity connection	0.70	0.46	0.74	0.44	0.72	0.45	0.79	0.41	0.76	0.43
Upazila experienced flooding in last 12 months	0.64	0.48	0.80	0.40	0.68	0.47	0.64	0.48	0.74	0.44

Appendix Table 4: Attendance at training sessions, by treatment arm

	T - N *(N = 1274)*	T - A *(N = 1266)*	T - AN *(N = 1242)*	T – ANG *(N = 1250)*
How many training sessions did you attend?				
Mean (SD)	14.68 (5.89)	14.20 (4.71)	27.58 (10.43)	29.16 (9.71)
Median (Q1, Q3)	17.0 (12.0, 19.0)	16.0 (12.0, 17.0)	32.0 (23.0, 35.0)	34.0 (28.0, 36.0)
How many training sessions did your spouse attend?				
Mean (SD)	13.95 (6.55)	13.82 (5.21)	26.56 (11.52)	28.12 (11.09)
Median (Q1, Q3)	16.0 (10.0, 19.0)	16.0 (12.0, 17.0)	32.0 (20.0, 36.0)	33.5 (25.0, 36.0)
Females: Percentage of trainings attended				
Mean (SD)	82.24 (25.40)	86.40 (22.75)	84.27 (24.06)	74.75 (18.42)
Median (Q1, Q3)	94.7 (78.9, 100.0)	94.1 (82.4, 100.0)	94.4 (83.3, 100.0)	79.5 (72.7, 81.8)
Males: Percentage of trainings attended				
Mean (SD)	75.23 (30.00)	81.47 (26.56)	73.64 (31.09)	66.64 (27.09)
Median (Q1, Q3)	89.5 (63.2, 100.0)	94.1 (70.6, 100.0)	88.9 (55.6, 100.0)	75.0 (54.5, 81.8)
Did you attend training together with your spouse?				
Yes	1030 (91.2%)	1022 (91.2%)	986 (88.5%)	986 (90.8%)
No	100 (8.8%)	98 (8.8%)	128 (11.5%)	100 (9.2%)
Why did you not attend all the training?				
Attended all sessions	435 (38.5%)	492 (43.9%)	333 (29.9%)	340 (31.3%)
Had to work in the agricultural field	75 (6.6%)	66 (5.9%)	97 (8.7%)	77 (7.1%)
Had to work in own work sector	429 (38.0%)	365 (32.6%)	432 (38.8%)	467 (43.0%)
Illness	122 (10.8%)	110 (9.8%)	179 (16.1%)	145 (13.4%)
Social obligation	40 (3.5%)	46 (4.1%)	50 (4.5%)	41 (3.8%)
Bad weather	10 (0.9%)	7 (0.6%)	9 (0.8%)	5 (0.5%)
Did not think this would be useful	19 (1.7%)	34 (3.0%)	14 (1.3%)	11 (1.0%)
If you miss any session, does the SAAO come to you?				
Yes	539 (60.1%)	505 (56.3%)	544 (56.2%)	655 (67.9%)
No	358 (39.9%)	392 (43.7%)	424 (43.8%)	309 (32.1%)
Does any other household member attend the training session as a substitute?				
Yes	88 (7.8%)	65 (5.8%)	128 (11.5%)	101 (9.3%)
No	1042 (92.2%)	1055 (94.2%)	986 (88.5%)	985 (90.7%)
Was there dissatisfaction among your husband and/or in-laws of you attending?				
Yes	55 (9.4%)	51 (8.8%)	57 (9.8%)	45 (7.9%)
No	528 (90.6%)	531 (91.2%)	525 (90.2%)	523 (92.1%)
If your husband refused to go, could you attend the training sessions alone?				
Yes	268 (46.0%)	278 (47.8%)	305 (52.4%)	322 (56.7%)
No	315 (54.0%)	304 (52.2%)	277 (47.6%)	246 (43.3%)

Appendix Table 5: Access and experience with training sessions

	T - N *(N = 1274)*	T - A *(N = 1266)*	T - AN *(N = 1242)*	T – ANG *(N = 1250)*
Distance (km) of the training venue from home (one way)				
Mean (SD)	0.54 (0.79)	0.64 (0.76)	0.64 (1.66)	0.52 (0.52)
Distance (minute) of the training venue from home (one way)				
Mean (SD)	11.28 (12.46)	11.72 (9.60)	11.74 (10.01)	10.43 (9.24)
How did you generally go to the training?				
Walking	1071 (95.1%)	1021 (91.5%)	1052 (94.9%)	1035 (95.3%)
By rickshaw	6 (0.5%)	12 (1.1%)	8 (0.7%)	8 (0.7%)
By van/nosimon/korimon	19 (1.7%)	39 (3.5%)	16 (1.4%)	20 (1.8%)
By boat	1 (0.1%)	0 (0.0%)	1 (0.1%)	1 (0.1%)
Combination of ricshshaw/van	7 (0.6%)	7 (0.6%)	2 (0.2%)	0 (0.0%)
Combination of ricshshaw/van/Boat	2 (0.2%)	2 (0.2%)	5 (0.5%)	2 (0.2%)
Other (specify)	20 (1.8%)	35 (3.1%)	24 (2.2%)	20 (1.8%)
What kind of difficulty did you face when coming to the training session?				
Rain	60 (5.3%)	71 (6.4%)	72 (6.5%)	80 (7.4%)
Vehicle was not available	9 (0.8%)	8 (0.7%)	5 (0.5%)	6 (0.6%)
Road condition was bad	30 (2.7%)	20 (1.8%)	18 (1.6%)	14 (1.3%)
Husband/Wife was not willing to come	1 (0.1%)	0 (0.0%)	2 (0.2%)	2 (0.2%)
Household members created obstacle	4 (0.4%)	3 (0.3%)	3 (0.3%)	4 (0.4%)
No difficulty	1019 (90.5%)	1009 (90.4%)	1005 (90.7%)	978 (90.1%)
Other (specify)	3 (0.3%)	5 (0.4%)	3 (0.3%)	2 (0.2%)
TRAINING QUALITY & CONDITIONS				
How were the contents of the training sessions?				
Very informative	903 (80.3%)	943 (85.0%)	948 (85.6%)	926 (85.3%)
Moderately informative	211 (18.8%)	157 (14.2%)	153 (13.8%)	156 (14.4%)
Most of the contents were already known	6 (0.5%)	3 (0.3%)	2 (0.2%)	3 (0.3%)
Topics were difficult to understand	2 (0.2%)	5 (0.5%)	3 (0.3%)	1 (0.1%)
Other (specify)	2 (0.2%)	1 (0.1%)	1 (0.1%)	0 (0.0%)
How did you like the way of delivery of the trainer?				
Very communicative and understandable	896 (79.7%)	979 (88.3%)	942 (85.1%)	903 (83.1%)
Moderately communicative and understandable	219 (19.5%)	123 (11.1%)	158 (14.3%)	181 (16.7%)
Delivery was too fast to understand	8 (0.7%)	3 (0.3%)	4 (0.4%)	2 (0.2%)
Trainer was reading out the manual and was not explaining	1 (0.1%)	1 (0.1%)	2 (0.2%)	0 (0.0%)
Others	0 (0.0%)	3 (0.3%)	1 (0.1%)	0 (0.0%)
Do you think the trainer was well prepared for the training?				
Trainer was very well prepared	938 (83.5%)	970 (87.5%)	965 (87.2%)	895 (82.4%)
Well-prepared	171 (15.2%)	129 (11.6%)	132 (11.9%)	183 (16.9%)
Moderately prepared	14 (1.2%)	10 (0.9%)	8 (0.7%)	6 (0.6%)
Not prepared	1 (0.1%)	0 (0.0%)	2 (0.2%)	2 (0.2%)
Did you always understand what was taught?				
Always	609 (54.2%)	605 (54.6%)	604 (54.6%)	562 (51.7%)

	T - N (N = 1274)	T - A (N = 1266)	T - AN (N = 1242)	T – ANG (N = 1250)
Mostly	415 (36.9%)	395 (35.6%)	398 (36.0%)	406 (37.4%)
Often	91 (8.1%)	99 (8.9%)	97 (8.8%)	108 (9.9%)
Seldom	8 (0.7%)	9 (0.8%)	8 (0.7%)	10 (0.9%)
Never	1 (0.1%)	1 (0.1%)	0 (0.0%)	0 (0.0%)
When you did not understand, did you ask the trainer to repeat?				
Yes	1019 (90.7%)	1030 (92.9%)	1009 (91.1%)	1013 (93.3%)
No	105 (9.3%)	79 (7.1%)	98 (8.9%)	73 (6.7%)
When you asked the trainer to repeat or explain again, how did s/he react?				
S/he repeated happily	960 (94.2%)	1004 (97.5%)	976 (96.7%)	967 (95.5%)
Told that s/he would explain to you later to avoid interrupt	57 (5.6%)	24 (2.3%)	29 (2.9%)	44 (4.3%)
Asked you to get help from other trainees	1 (0.1%)	2 (0.2%)	4 (0.4%)	1 (0.1%)
Ignored your request	1 (0.1%)	0 (0.0%)	0 (0.0%)	1 (0.1%)
Did you receive any training brochure/poster?				
Yes	1060 (94.3%)	992 (89.4%)	1081 (97.7%)	1050 (96.7%)
Did you find the brochure/poster helpful?				
Yes	1048 (98.9%)	960 (96.8%)	1047 (96.9%)	1031 (98.3%)
No	5 (0.5%)	7 (0.7%)	8 (0.7%)	7 (0.7%)
I did not check	7 (0.7%)	25 (2.5%)	26 (2.4%)	11 (1.0%)
Did you discuss the learnings from the training sessions with your spouse?				
Yes	1075 (95.6%)	1058 (95.4%)	1066 (96.3%)	1045 (96.2%)
Did you discuss the learnings with other fellow trainees?				
Yes	1064 (94.7%)	1051 (94.8%)	1038 (93.8%)	1026 (94.5%)
Did you ever share your learning with other household members?				
Yes	1058 (94.1%)	1023 (92.2%)	1019 (92.1%)	1008 (92.8%)

Appendix Table 6: Women's perception of training sessions

	T - N (N = 637)	T - A (N = 633)	T - AN (N = 621)	T – ANG (N = 625)
Were the training sessions helpful?				
Yes, very helpful	569 (97.6%)	562 (96.9%)	564 (97.2%)	555 (97.7%)
Somewhat helpful	10 (1.7%)	18 (3.1%)	16 (2.8%)	12 (2.1%)
Not helpful	4 (0.7%)	0 (0.0%)	0 (0.0%)	1 (0.2%)
If yes, how was the training helpful?				
Post-training increase in income	61 (10.7%)	124 (22.1%)	144 (25.5%)	138 (24.9%)
Learnt new agricultural practices	72 (12.7%)	327 (58.2%)	207 (36.7%)	201 (36.2%)
Childcare and nutrition	339 (59.6%)	82 (14.6%)	156 (27.7%)	163 (29.4%)
Maternal care and nutrition	67 (11.8%)	18 (3.2%)	37 (6.6%)	33 (5.9%)
Intra-household relationship improved	7 (1.2%)	7 (1.2%)	3 (0.5%)	11 (2.0%)
Household health status improved	8 (1.4%)	1 (0.2%)	10 (1.8%)	5 (0.9%)
Children's health improved	13 (2.3%)	2 (0.4%)	7 (1.2%)	3 (0.5%)
Other (specify)	2 (0.4%)	1 (0.2%)	0 (0.0%)	1 (0.2%)
Do you feel that you have gained more respect/status within your house				
No	41 (7.0%)	45 (7.8%)	28 (4.8%)	35 (6.2%)
No, because I have always been respected	107 (18.4%)	126 (21.7%)	84 (14.5%)	63 (11.1%)
Yes	435 (74.6%)	409 (70.5%)	468 (80.7%)	470 (82.7%)
Do you feel more confident in making decisions about spending money?				
No, I do not feel more confident	26 (4.5%)	40 (6.9%)	31 (5.3%)	23 (4.0%)
No, because I had enough confidence before	104 (17.8%)	113 (19.5%)	60 (10.3%)	55 (9.7%)
Yes	453 (77.7%)	427 (73.6%)	489 (84.3%)	490 (86.3%)
Do you feel that you have gained more respect within the community?				
No	69 (11.8%)	74 (12.8%)	64 (11.0%)	65 (11.4%)
No, because I have always been respected	95 (16.3%)	95 (16.4%)	62 (10.7%)	58 (10.2%)
Yes	419 (71.9%)	411 (70.9%)	454 (78.3%)	445 (78.3%)
Did the group participation result in solidarity/close ties among participants?	522 (89.5%)	532 (91.7%)	549 (94.7%)	528 (93.0%)
Yes	61 (10.5%)	48 (8.3%)	31 (5.3%)	40 (7.0%)
Did participation in the program interfere with your domestic responsibilities?				
Yes	180 (30.9%)	206 (35.5%)	198 (34.1%)	144 (25.4%)
Do you meet with any new friends after training?				
Yes	507 (87.0%)	517 (89.1%)	546 (94.1%)	523 (92.1%)

Appendix Table 7: Men's perception of training sessions

	T - N *(N = 637)*	T - A *(N = 633)*	T - AN *(N = 621)*	T - ANG *(N = 625)*
Were the training sessions helpful?				
Yes, very helpful	494 (91.3%)	504 (95.5%)	510 (96.8%)	495 (95.6%)
Somewhat helpful	45 (8.3%)	24 (4.5%)	15 (2.8%)	23 (4.4%)
Not helpful	2 (0.4%)	0 (0.0%)	2 (0.4%)	0 (0.0%)
If yes, how was the training helpful?				
Post-training increase in income	112 (22.7%)	142 (28.2%)	127 (24.9%)	138 (27.9%)
Learnt new agricultural practices	170 (34.4%)	303 (60.1%)	299 (58.6%)	251 (50.7%)
Childcare and nutrition	170 (34.4%)	49 (9.7%)	64 (12.5%)	78 (15.8%)
Maternal care and nutrition	12 (2.4%)	4 (0.8%)	3 (0.6%)	9 (1.8%)
Intra-household relationship improved	6 (1.2%)	5 (1.0%)	3 (0.6%)	7 (1.4%)
Household health status improved	16 (3.2%)	1 (0.2%)	8 (1.6%)	8 (1.6%)
Children's health improved	7 (1.4%)	0 (0.0%)	6 (1.2%)	3 (0.6%)
Other (specify)	1 (0.2%)	0 (0.0%)	0 (0.0%)	1 (0.2%)
Do you feel that you have gained more respect/ status within your house				
No	46 (8.5%)	45 (8.5%)	37 (7.0%)	46 (8.9%)
No, because I have always been respected	89 (16.5%)	124 (23.5%)	92 (17.5%)	122 (23.6%)
Yes	406 (75.0%)	359 (68.0%)	398 (75.5%)	350 (67.6%)
Do you feel more confident in making decisions about spending money?				
No, I do not feel more confident	41 (7.6%)	37 (7.0%)	36 (6.8%)	41 (7.9%)
No, because I had enough confidence before	91 (16.8%)	120 (22.7%)	92 (17.5%)	123 (23.7%)
Yes	409 (75.6%)	371 (70.3%)	399 (75.7%)	354 (68.3%)
Do you feel more confident in making decisions about spending money?				
No, I do not feel more confident	41 (7.6%)	37 (7.0%)	36 (6.8%)	41 (7.9%)
No, because I had enough confidence before	91 (16.8%)	120 (22.7%)	92 (17.5%)	123 (23.7%)
Yes	409 (75.6%)	371 (70.3%)	399 (75.7%)	354 (68.3%)
Do you feel that you have gained more respect within the community?				
No	61 (11.3%)	55 (10.4%)	40 (7.6%)	62 (12.0%)
No, because I have always been respected	89 (16.5%)	127 (24.1%)	115 (21.8%)	136 (26.3%)
Yes	391 (72.3%)	346 (65.5%)	372 (70.6%)	320 (61.8%)
Did the group participation result in solidarity/close ties among participants?				
Yes	464 (85.8%)	460 (87.3%)	473 (89.8%)	471 (90.9%)
Does participation in the program interfere with your domestic responsibilities				
Yes	278 (51.4%)	307 (58.3%)	318 (60.3%)	327 (63.1%)
Do you meet with any new friends after training?				
Yes	423 (78.2%)	431 (81.8%)	448 (85.0%)	434 (83.8%)

Appendix Table 8: Knowledge and adoption of improved agricultural production practices, crops, livestock, fish, female

	Control Endline	T-N	T-A	T-AN	T-ANG	T-N = T-A	T-N = T-AN	T-N = T-ANG	T-A = T-AN	T-A = T-ANG	T-AN = T-ANG
	Mean (SE)			*Coefficient (SE)*					*P-value*		
Knowledge, improved crop practices	5.47	0.964***	4.459***	4.936***	4.785***	<0.01	<0.01	<0.01	0.02	0.26	0.56
	0.19	0.23	0.198	0.213	0.299						
Knowledge, improved livestock practices	8.92	0.793***	3.469***	3.367***	3.157***	<0.01	<0.01	<0.01	0.66	0.12	0.29
	0.25	0.206	0.22	0.228	0.199						
Knowledge, improved fishpond practices	2.02	0.065	0.488***	0.502***	0.522***	<0.01	<0.01	<0.01	0.83	0.62	0.72
	0.08	0.074	0.06	0.057	0.06						
				Marginal Effect (SE)					*P-value*		
Adoption, improved crop practices	0.35	1.032**	4.232***	4.504***	4.361***	<0.01	<0.01	<0.01	0.31	0.65	0.59
	0.07	(0.400)	(0.629)	(0.729)	(0.705)						
Adoption, improved livestock practices	0.31	0.896***	3.123***	3.278***	3.357***	<0.01	<0.01	<0.01	0.48	0.33	0.81
	0.07	(0.321)	(0.467)	(0.525)	(0.450)						
Adoption, improved fishpond practices	0.19	0.028	0.377***	0.293***	0.281***	<0.01	<0.01	<0.01	0.29	0.18	0.71
	0.04	(0.047)	(0.069)	(0.070)	(0.064)						

Note: Estimates are intent-to-treat. Standard errors adjusted for clustering at block level are in parentheses. *p<.10; **p<.05; ***p<.01. All specifications include as independent variables the treatment indicators and the control variables listed in the notes to Table 1.

Appendix Table 9: Knowledge and adoption of improved agricultural production practices, crops, livestock, fish, male

	Control Endline	T-N	T-A	T-AN	T-ANG	T-N = T-A	T-N = T-AN	T-N = T-ANG	T-A = T-AN	T-A = T-ANG	T-AN = T-ANG
	Mean (SE)			*Coefficient (SE)*					*P-value*		
Knowledge, improved crop practices	5.84	1.133***	3.105***	3.108***	3.041***	<0.01	<0.01	<0.01	0.99	0.75	0.75
	0.17	0.187	0.191	0.205	0.198						
Knowledge, improved livestock practices	8.15	1.401***	2.560***	2.460***	2.604***	<0.01	<0.01	<0.01	0.68	0.84	0.49
	0.21	0.233	0.243	0.244	0.212						
Knowledge, improved fishpond practices	2.55	0.099**	0.238***	0.193***	0.153***	<0.01	<0.01	0.28	0.36	0.08	0.36
	0.05	0.047	0.05	0.041	0.041						
				Marginal Effect (SE)					P-value		
Adoption, improved crop practices	0.30	0.980***	2.230***	2.017***	1.987***	<0.01	<0.01	<0.01	0.29	0.28	0.88
	0.06	(0.223)	(0.306)	(0.324)	(0.325)						
Adoption, improved livestock practices	0.18	0.691***	1.604***	1.785***	1.652***	<0.01	<0.01	<0.01	0.19	0.78	0.45
	0.04	(0.200)	(0.280)	(0.312)	(0.319)						
Adoption, improved fishpond practices	0.22	0.156***	0.220***	0.234***	0.216***	0.14	0.06	0.23	0.74	0.95	0.73
	0.04	(0.050)	(0.571)	(0.056)	(0.060)						

Note: Estimates are intent-to-treat. Standard errors adjusted for clustering at block level are in parentheses. *p<.10; **p<.05; ***p<.01. All specifications include as independent variables the treatment indicators and the control variables listed in the notes to Table 1.

Appendix Table 10: Impact on additional measures of diet, DDS and FCS

	Control	T-N	T-A	T-AN	T-ANG	T-N = T-A	T-N = T-AN	T-N = T-ANG	T-A = T-AN	T-A = T-ANG	T-AN = T-ANG
	Mean (SE)	*Marginal Effect (Standard Error)*				*P-value*					
Dietary Diversity Score (DDS)	7.7	0.203**	0.207**	0.397***	0.348***	0.96	0.02	0.10	0.02	0.11	0.54
	(0.13)	(0.083)	(0.081)	(0.075)	(0.080)						
		Coefficient (Standard Error) [Marginal Effect]									
Log Food Consumption Score	69.4	0.025	0.029	0.059***	0.064***	0.83	0.07	0.04	0.09	0.09	0.78
	(1.50)	0.019	0.018	0.016	0.018						
				0.060	0.067						

Note: Estimates are intent-to-treat. Where statistically significant at p < 0.10, marginal effects (ME) are reported using the method found in Bellemare and Wichman (2020). Standard errors adjusted for clustering at block level are in parentheses. *p<.10; **p<.05; ***p<.01. Both specifications include as independent variables the treatment indicators, and the control variables listed in the notes to Table 1. The DDS results also include the baseline value of DDS as a control variable. For DDS, a Poisson estimator is used and the coefficients converted to marginal effects.

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