SECURING WATER FOR FOOD

Adaptive Symbiotic Technologies (AST) Performance Evaluation

BioEnsure® Fungal Seed and Plant Treatment in India

AUGUST 2019

SECURING WATER FOR FOOD: A GRAND CHALLENGE FOR DEVELOPMENT

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ABSTRACT

The Indian state of Rajasthan is the most severely drought-affected state in the country with the highest probability of rainfall deficiency and drought occurrence. In the Rajasthan district of Nagaur, farmers mostly rely on rainfall for their crops (used for over 70 percent of net sown area). With a predicted acceleration in drought occurrence in the district, the ability of farmers to adapt to low water supplies is put to a test. The seed treatment innovation BioEnsure – developed by agro-tech company Adaptive Symbiotic Technologies (AST) – may be able to aid Nagaur farmers with this challenge by increasing less-than-normal rainfall crop yields and crop resilience to droughts and heatwaves.

Since 2015, AST has conducted a seed treatment project in a handful of villages in Nagaur, in partnership with the Securing Water for Food Grand Challenge (SWFF). This report is an inquiry into the benefits farmers in these villages have received from the AST project in terms of crop yields, crop survival rates, and family income. Interviews with 50 innovation users and field observations were conducted in July and August 2019.

Findings show a majority of innovation users experienced an increase in crop yields, crop survival rates, and water efficiency. Although increases in crop yields and crop survival rates can have many causes, such as seasonal variations in rainfall, temperature, and wind, comparisons of pre- and post-treatment harvests under similar conditions implies that experienced benefits primarily can be ascribed to the BioEnsure innovation.

INTRODUCTION

In India, rainfed agriculture constitutes about 55 percent of the subcontinent's net sown area, land that hosts 40 percent of the total population. However, in Rajasthan, the state where the AST BioEnsure project was implemented, reliance on rainfed agriculture is estimated at more than 70 percent of the net sown area (NRAA, 2012). Of the 50 innovation users interviewed for this report, only two large scale farmers supplement rain with other irrigation means. The lack of rainfed irrigation alternatives in the region results in most farmers performing agriculture for one crop cycle per year (usually stretching from July to October).

In India, 80 percent of annual rainfall is from the southwest monsoon that occurs between June and September. The monsoon's arrival creates the world's most agriculturally productive wet season. Monsoon season is especially critical for Indian states in low rainfall belts like Rajasthan. Climate variability can contribute to monsoon deficiency in these areas, which increases the drought frequency that is now, on average, once every four years. Among the 13 Indian states most frequently reported as drought-prone, Rajasthan is the most severely affected with the highest probability of rainfall deficiency and drought occurrence (Mundetia and Sharma, 2015). In this new reality, it is imperative that farmers adopt more climate resilient solutions.

AST was founded in 2011 and is based in Seattle, Washington. AST has performed pilot projects and commercially introduced its biological seed treatment innovation, BioEnsure, in arid and semi-arid areas in countries including the United States, India, Kenya, Peru, and Australia.

The BioEnsure innovation is a mixture of non-toxic and non-pathogenic fungi microbes (known as endophytes) that are applied to the crop seed before planting. As the plant begins to grow, the fungi enters the plant and establishes a symbiotic relationship with its host plant. In field trials, the innovation has helped its partner crop become more nutrient efficient, consume less water, yield more produce, and better able to tolerate environmental stresses such as heat waves, droughts, and salinization. According to AST, the BioEnsure innovation increases crop yields with an average of two to six percent during low stress growing conditions and 10 to 50 percent in high stress growing conditions (Adaptive Symbiotic Technologies, 2019).

The potential of the BioEnsure innovation to help reduce crop water consumption and increase crop yields for farmers in the drought and heat wave ravaged state of Rajasthan was recognized by Securing Water for Food (SWFF). In 2015, SWFF awarded AST a grant to assist in introducing the BioEnsure innovation to farmers in Rajasthan using seed treating solutions they can administer by using simple technology.

This report is based on interviews and field observations completed in July and August of 2019 in villages and dhanis (small family communities) in the Indian district of Nagaur situated in Rajasthan state (Map 1). Of the 366 people that treated their seeds with the BioEnsure innovation in 2016 and 2017, 50 users were interviewed (49 individual and 1 group interview). Visits were made to 20 percent of the user's fields to observe and photograph different stages of the crop cycle.

MAP 1: NAGAUR'S POSITION IN INDIA

BACKGROUND

Interviews were conducted in the Rajasthan district Nagaur in the villages and dhanis of: Altawa (five interviews), Barnel (four), Bugala (three), Choyala Ki dahni (four), Guda Chak 2 (six), Itawa Lakha (four), Khedi Silla (eight), Lodiya Ki dhani (three), Palri Mahesh (six), Pusa Ji Nodal Ki dahni (two), and Rampura (five) (Map 2).

Interviews were conducted by the field evaluator with the assistance of a local interpreter because most innovation users were more comfortable speaking in a local Hindi dialect. Answers were recorded in a notebook and later transcribed into digital format using a mobile application. To resolve any post-interview note ambiguities, interviews were also recorded using a mobile phone audio recording application.

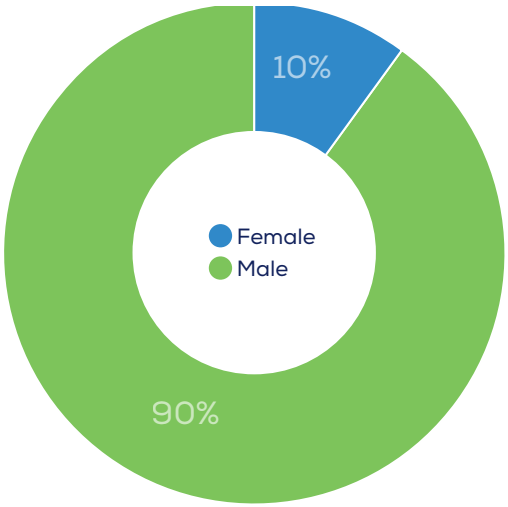
MAP 2: LOCATIONS OF VILLAGES AND DHANIS OF INTERVIEWED INNOVATION USERS

Gender

Approximately 48 percent of Rajasthan's population is female. In the Rajasthan district of Nagaur, the female to male ratio is similar to the state as a whole. In Nagaur, 35 percent of women perform some sort of wage labor, compared with 50 percent of men. Farmers and agricultural laborers, the main targets of this report, account for 87 percent (495,459 people) of the total active female labor force and 59 percent (502,556 people) of the total active male labor force (Census of India 2011).

Data shows that in Rajasthan as a whole and in Nagaur, women face a harsher reality than the average Indian woman. Rajasthan has some of the worst results of all Indian states for gender equity indicators, such as child sex ratio, gender gap in school attendance, literacy levels, and maternal mortality (World Bank, 2016). Traditional customs are still practiced in Nagaur, including separation of female and male attendants at major social events.

FIGURE 1: GENDER OF INNOVATION USERS
N=50



Of the innovation users interviewed, 10 percent (five) were female and 90 percent (45) were male (Figure 1). The discrepancy in gender distribution of the interviewees and that of total farmer and agricultural labor force is because the 366-person user list provided by AST contained only four female users. During field research, local inhabitants indicated that it is traditionally considered the husband's role to organize matters related to attaining agriculture inputs. This is a plausible explanation for why so few women attended the AST seed treatment facilities in 2016 and 2017.

Farm size

Among users, 48 own agricultural land. Of these landowners, 27 also are renting land to increase their harvests and earnings on the premise that they can keep 50 percent of the harvested crops grown on the rented land.

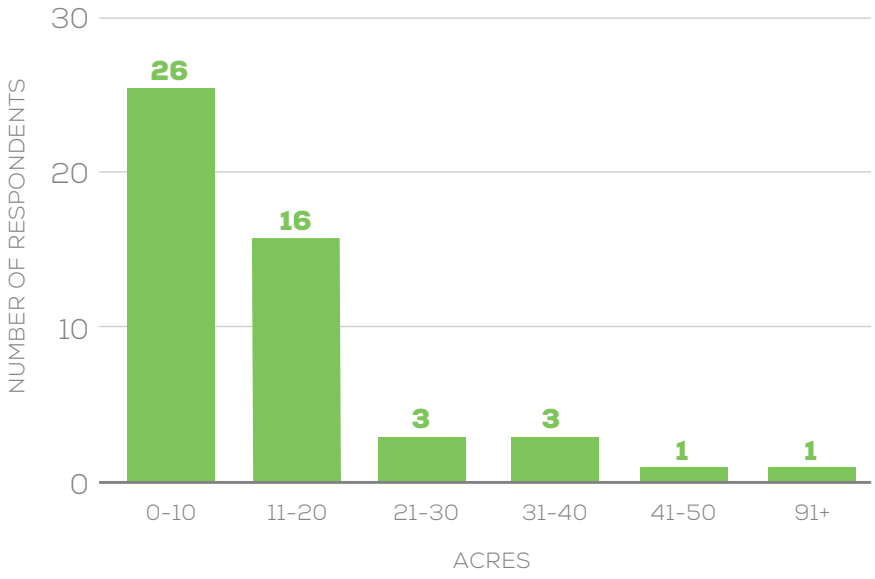
In the region, land area is measured in bigha, with one bigha equal to roughly 0.62 acres or 0.25 hectares. The farm sizes of the respondents ranged from three bigha to 150 bigha. The average farm size of respondents is 21.7 bigha, while the median is 15.5 bigha (Table 1). Farmers who rent land increased on average the area they grew crops on by 54 percent.

TABLE 1: RESPONDENT FARM SIZE

	BIGHA	ACRES	HECTARES
Average	21.71	13.46	5.42
Median	15.50	9.61	3.87
Total	**1085.50**	**673.01**	**271.37**

When dividing respondent farm size answers into six equally large intervals (10 acres each) most were within the "0-10 acres" (26) and "11-20 acres" (16) intervals (Figure 2).

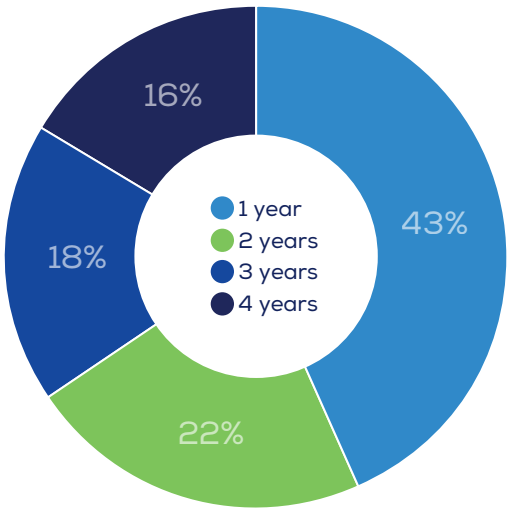
FIGURE 2: FARM SIZE DISTRIBUTION



Farmer's experience

The innovation was first introduced to Rajasthan farmers and landowners in 2015. Farmers got their seeds treated free of charge for the first two years. Free treatment was a strategy to promptly spread the word about the benefits first-year users had when using the innovation. The time respondents spent using the innovation ranged from one to four years (Figure 3).

FIGURE 3: YEARS USING THE INNOVATION
N=50



Other occupations or sources of income

Of the users, 40 indicate agriculture as their sole source of income. Of the other 10, two do not practice farming at all, getting their income from running small private enterprises and renting their land to other farmers. The remaining eight users include two people with wage labor as their primary source of income and farming as their secondary; four people with farming as their primary source of income and small enterprises as their secondary (e.g., diary, carpentering, and plowing/sowing enterprises); one has a small enterprise as his primary source of income and farming as his second; and one has farming as his primary source of income and is also receiving remittance incomes from his children who work abroad.

Family size and age distribution

In the countryside of Rajasthan, family units often are organized in communities called "dhani" in Hindi. Dhanis typically consist of siblings in a family, along with their respective spouses, children, and in-laws, who have chosen to build their houses close to each other and often share the same patio. The relatives also share labor efforts, as well as agricultural and household expenses. This type of family composition explains the large family sizes of some innovation users.

Family sizes among users range from a single person household to a 25-member household. The average family size is 7.5 members, and the median is six members (Figure 4). The age of users ranges from 27 to 83 years old, with an average of 54.66 years (Figure 5).

FIGURE 4: FAMILY SIZE OF RESPONDENTS

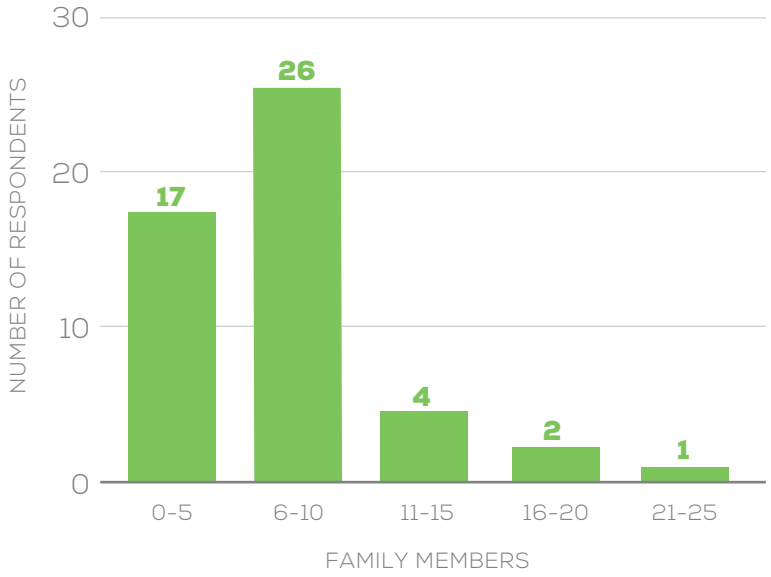
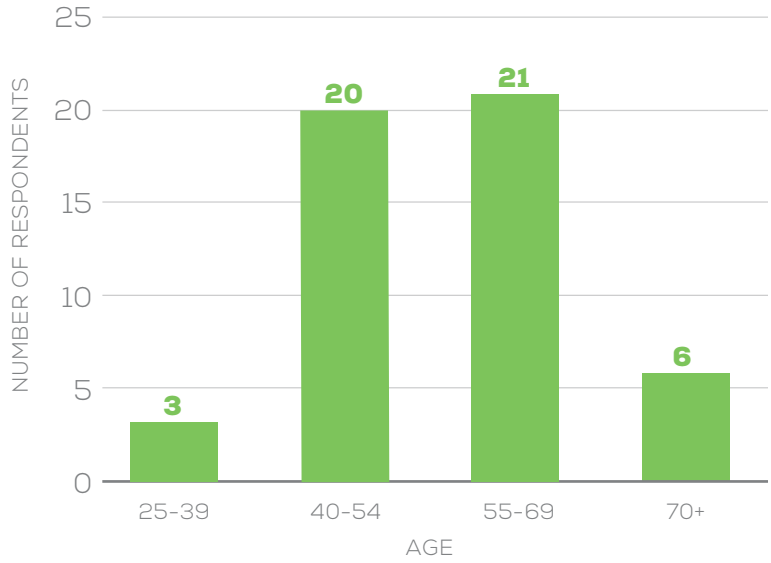


FIGURE 5: AGE DISTRIBUTION OF RESPONDENTS



METHODOLOGY

Sample Selection

AST provided lists of innovation users who received seed treatment in 2016 and 2017. The lists contained 366 innovation users (70 users for 2016 and 296 for 2017) residing in 13 villages and four dhanis.

A random cluster interview sample was selected from the user lists using a mobile application. The sample size consisted of 150 innovation users and corresponded proportionally to the total number of users in each village and dhani during 2016 and 2017. The sample size of 150 innovation users was purposely tripled to achieve the intended 50 interviews. This allowed for a buffer to accommodate uncertainties, such as interviewee prospects being unavailable or unwilling to participate at the time of the field visits.

Roads in the geographical area where BioEnsure innovation users live and practice agriculture are unpaved and lack road signs. Agricultural land plots are scattered and often not directly adjacent to the house of the farmer owning or renting the plot. Local coordinators and villagers facilitated locating farmers and getting them to agree to be interviewed. All innovation users from the random sample who could be located agreed to be interviewed. About two-thirds of the interviews were conducted in the user's home while one-third took place during a work break in the farmer's field.

Interviews were conducted in person with assistance from a local interpreter who spoke the specific Hindi dialect of Nagaur. Answers were recorded in a notebook and as audio using a mobile phone recording application. Answers were then transferred to the Fulcrum mobile data collection platform for further analysis.

As interviews were conducted, it became clear that questions about annual household income, earnings before/after use of innovation, and percentage of income from non-farm sources were not popular with users. Most users either refused to answer these questions or gave answers that likely were incorrect. For example, farmers who could be identified as wealthier than the rural average (i.e., owning tractors, agricultural machines, and homes with marble floors) claimed their annual average income was within the "extremely poor" wealth category (INR 0-160,000; USD $0-2,250). To reduce their reluctance to respond with a precise income, users were asked to indicate which of four intervals best described their income. This was ineffective since all users pointed to the lowest interval.

RESULTS

EXPERIENCE WITH INNOVATION

Innovation users were asked if changes in temperature and rainfall in recent years have affected their farming compared to their crop yields during historical cropping seasons. Of the 50 users, 47 answered yes. When asked to elaborate on how these changes affected their farming, a common thread became apparent as they recalled that during the later years, one out of three harvest seasons had insufficient rainfall for the crop to reach full potential. Users shared that another challenge in later years was monsoon seasons with excessive rainfall, arriving occasionally in the interval between drought years and washing away entire crops sown in low-lying fields. The innovation has not been able to resolve the later challenge; however, 44 of 50 users (88 percent) indicated that using the innovation increased crop survival rate during prolonged drought.

Although a few users expressed they were expecting more from the innovation, the majority of users are positive or very positive about their experience. When asked if they would continue using the innovation five to 10 years from now, 42 (84 percent) of respondents answered yes, seven (14 percent) answered no, and one (2 percent) answered that he did not know because his son-in-law was now responsible for agriculture decisions.

When asked if they would recommend the innovation to other farmers, the majority answered that they either "would recommend" (37 users) or "would strongly recommend" (2 users) the innovation to other farmers.

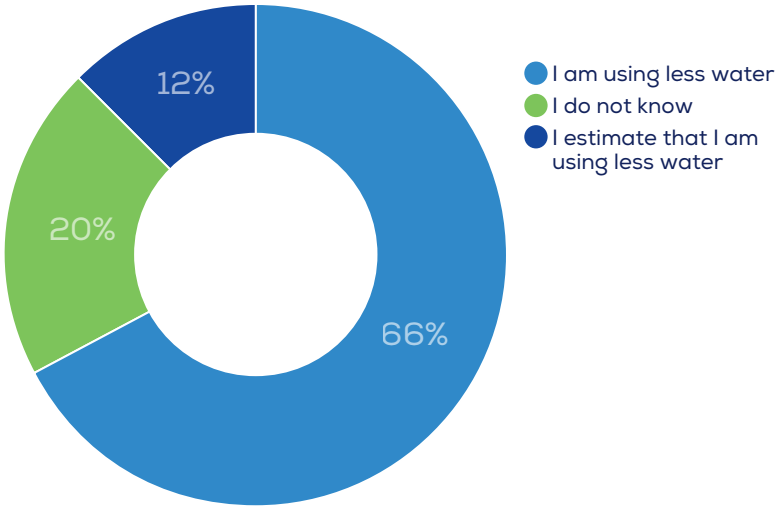
Prior to the innovation, many users were exclusively using seeds purchased in a regional seed market, with prices per kilogram of up to USD $7. After the innovation became available in their area, the same farmers were able to compare yields achieved with market seeds to yields achieved with seeds from previous growing seasons that were treated with the innovation fungi solution. When asked about the benefits of using the innovation, 17 users cited having the same or higher yields than with markets seeds at a considerably lower price (seed input costs range up to USD $1.50 per kilogram of treated seeds when using saved seeds) as the innovation's main benefit.

BENEFITS OF INNOVATION

Water benefits

A relatively large proportion (68 percent) of interviewees reported not knowing if they are using less water because of the innovation (Figure 6). This may be due to the scarcity of readily available groundwater in the region, which causes all but two users to rely completely on rainwater for irrigation. Therefore, it is hard to observe how much water is actually used. It is worth noting that two interviewees reported using less water and estimated this reduction had been as great as one-third less water consumed. Also, worth noting is that one of the farmers in the group using less water is also one who irrigates parts of his crop with groundwater from tubewells. He claims a decrease in the amount of water he consumes from his well.

FIGURE 6: CHANGE IN WATER USE
N=50



Crop benefits

When asked about the main benefits of the innovation, the most frequent answer (40 times) was that it helped produce more of their most important crop.

Using rainwater almost exclusively, the users all grow one or several of the same four crops. In order of importance, these are: mung beans, pearl millet (bajra in Hindi), cluster beans (gawaar in Hindi), and moth beans. Mung beans are considered the most important by most of the farmers because it has the best sale price-input costs ratio (Table 2).

TABLE 2: RECEIVED CROP PRICE

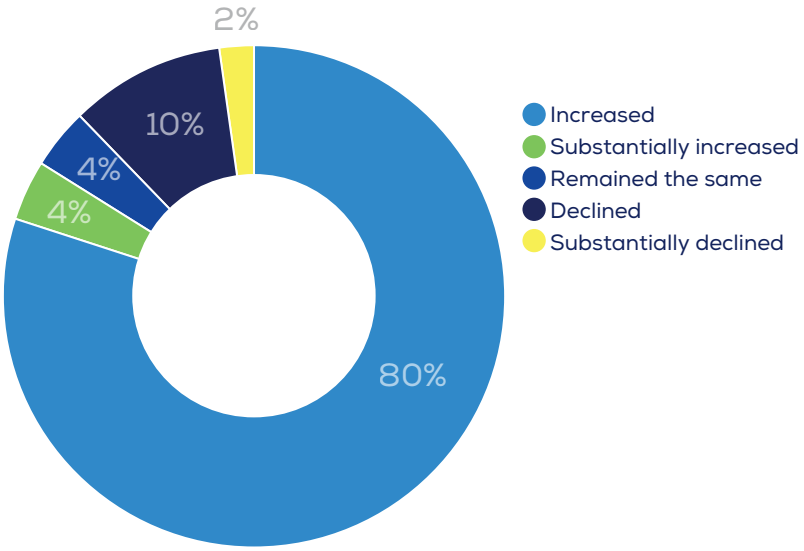
CROP	MUNG	PEARL MILLET	CLUSTER BEANS	MOTH BEANS (only grown by one farmer)
Price per kg (INR)	40-60*	10-18	30-40	50

*One farmer received as much as INR. 70 per kg mung by being accepted to a state funded purchasing program

Mung is almost exclusively grown by the interviewed farmers as a cash crop, and most farmers save a small amount of their mung harvest for re-sowing the next harvest season (50 to 200 kilograms, depending on farm size). Pearl millet is consumed to a much larger extent by the users themselves, with 23 users keeping 30 to 100 percent of their crop yield for their own household.

Users were generally very positive when asked if the BioEnsure seed treatment had improved their yields (Figure 7). Forty-two of 50 respondents (84 percent) felt their yields had either increased or substantially increased. Another two respondents (four percent) felt yields had remained the same, although one stated, "The year we used the innovation, we had a severe challenge with excessive weeds resulting in our mung yield being very badly affected; if this would not have been the case I believe that our yield could have been doubled." Another six respondents (12 percent) reported their yields had declined or substantially declined.

FIGURE 7: CHANGE IN CROP YIELDS USING BIOENSURE*
N=50



* The question that this figure is based on did not probe whether respondents were comparing innovation treated seeds to untreated saved seeds or untreated market seeds. The figure therefore shows respondents' changes in crop yield comparing use of untreated seeds in general with use of innovation treated seeds.

Of the respondents reporting an increase or a significant increase in crop yields using BioEnsure treated seeds, nine quantified the increase in crop yield they had experienced (Table 3).

TABLE 3: QUANTIFIED YIELD INCREASE

INNOVATION USER	1	2	3	4	5	6	7	8	9
Yield increase compared to untreated own seeds	20%	30%	30%	15%	33%	40%	–	–	50%
Yield increase compared to market seeds	–	–	–	–	–	–	25%	30%	

A similar response distribution to the question about changes in crop yields (Table 3) is found in responses to the question "Did the BioEnsure seed treatment increase the survival rates of crops?" (Table 4). One farmer explained how the innovation increased his crop survival rates, "The increased growth speed it gave my plants makes for a shorter crop cycle and hence a shorter time that the crops can be damaged by weather events and different pests."

TABLE 4: INCREASE IN CROP SURVIVAL RATE

Yes	44 respondents	88%
No	6 respondents	12%

Income benefits

As mentioned in the methodology, most respondents were reluctant to answer questions related to income. A clear skew toward reporting lower rather than actual income has been noted through field observations. For example, several interviews were conducted in respondent homes with televisions and tractors although the respondent claimed to have an annual income in the "extreme poor" category. In fact, 47 of 50 respondents (94 percent) claimed to be in this income group (Table 5).

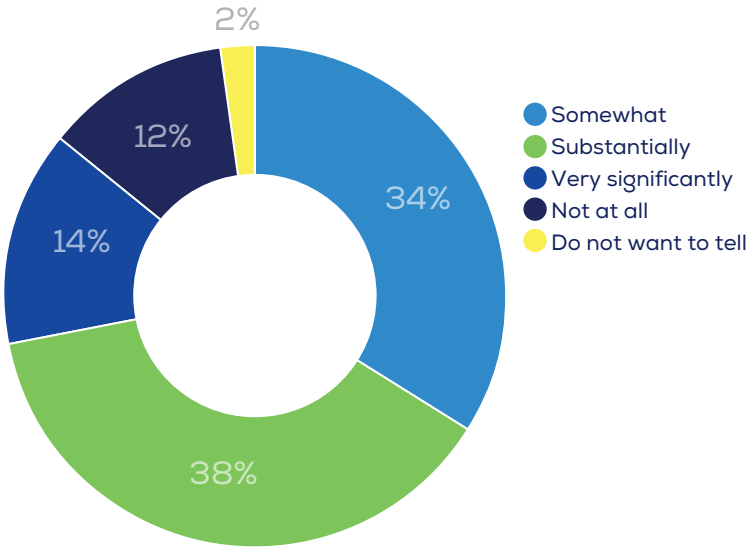
TABLE 5: REPORTED ANNUAL INCOME

ANNUAL INCOME (INR)	EXTREME POOR (0-160,000)	LOW INCOME (160,001-320,000)	MIDDLE INCOME (320,001-480,000)	UPPER INCOME (480,000+)
Number of respondents	47	2	1	0
Percentage of total	**94%**	**4%**	**2%**	**0%**

When asked what their crop incomes were before and after the innovation introduction, only one user gave an exact answer. Before the innovation, he made INR. 50,000 (approximately USD $700) and reported his income increased to INR. 80,000 (approximately USD $1,200) afterward. Similarly, when asked about income from non-farm sources, only nine users answered. Of these nine, seven reported no non-farm sources of income, one reported an annual income of INR. 120,000 (approximately USD $1,700) from non-farm sources, and one indicated an annual income of INR. 200,000 (approximately USD $2,800).

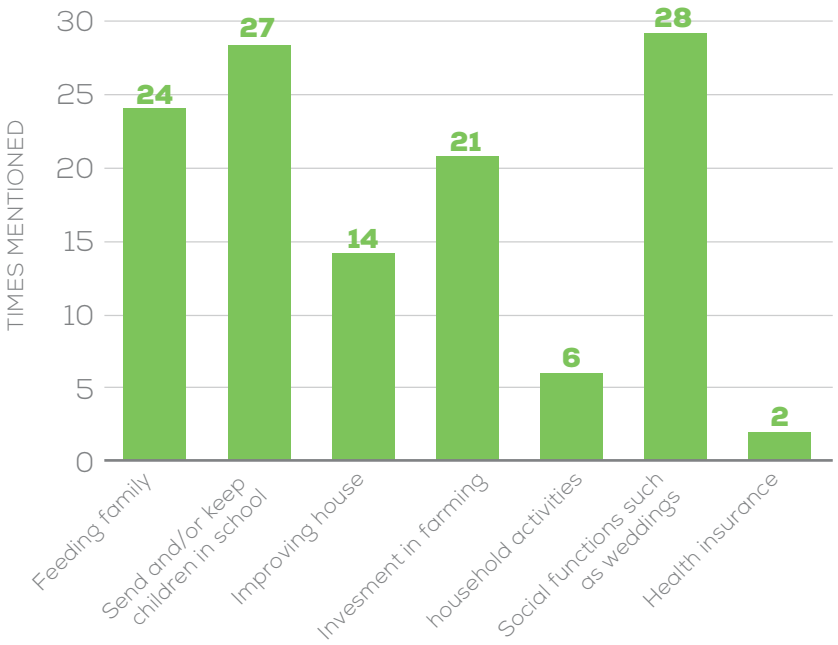
Conversely, when asked how much their family income had improved with the use of the innovation, 49 of 50 respondents felt comfortable providing an answer. More precisely, 52 percent were experiencing a "significant" or "very significant" improvement in their family income, 34 percent indicated "somewhat" improvement, 12 percent said no improvement at all, and 2 percent did not want to share this information (Figure 8).

FIGURE 8: IMPROVEMENT OF FAMILY INCOME
N=50



Respondents spend their additional income in a variety of ways, including on their children's school expenses, for social functions such as marriages, and on feeding their family. Other common ways to spend this income is on house improvements and investments in agriculture (Figure 9).

FIGURE 9: SPENDING OF NEW INCOME



Input spending

The second most frequently mentioned (17 times) main benefit of using the innovation was helping lower input costs.

Respondents were asked about their use of agricultural inputs before and after the introduction of the BioEnsure seed treatment into their farming. This included questions about their usage of and spending on seeds, fertilizer, pesticide, herbicide, charcoal (as a natural pesticide), water, and family and hired labor. Except for spending on seeds, no differences were found in usage or spending on these agriculture inputs when compared to the period before and after the BioEnsure introduction. This is not surprising given that the BioEnsure seed treatment does not include provision of any previously used inputs or training in input efficiency. The latter, in the form of advice on how to improve farming water use efficiency, was proposed as a complementary addition to the innovation by one farmer. Concerning differences in seed spending, farmers that had switched from buying new market seeds every year to reusing their own seed and treating them with the BioEnsure solution reported saving on average INR. 53,700 (USD $756) per harvest cycle, with reported savings ranging from INR. 350 to 420 per kilogram of seeds.

Usage of non-seed agricultural inputs varied considerably in terms of the extent they were taken advantage of, which ranged from hired labor that all respondents reported using to herbicide usage reported by two users (Table 6).

TABLE 6: INPUT SPENDINGS PER ACRE

	DIAMMONIUM PHOSPHATE (DAP)	UREA	PESTICIDES	HERBICIDES	LABOR*
Number of users	21	19	23	2	50
Average spending per acre (INR)	170	30	340	10	4920
Range of spending per acre (INR)	16-630	10-290	130-1600	240-320	3220-7740

*Since a considerable quantity of agriculture labor is done by family members, this number is likely to be inflated.

When asked about crops grown before and after being introduced to the innovation, seven of 50 respondents reported changes in crop selection. These users had stopped growing one of the crops grown prior to the innovation (Table 7).

TABLE 7: CHANGES IN CROPS GROWN

INNOVATION USER	1	2	3	4	5	6	7
Crop removed after innovation introduction	Pearl millet	Beans	Pearl millet	Beans	Wheat	Pearl millet	Pearl millet

Gender differences

The average size of farmland owned by the households of female respondents is 4.8 acres (7.8 bigha) and 14.4 acres (23.3 bigha) for the households of male respondents.

No clear trends distinguishing female from male answers to questions about the experienced benefits of using the innovation and how potential new income was spent. However, when asked about their overall perception of the innovation, all female respondents indicated they "would recommend it," while 75 percent of male respondents said they "would recommend it" or "would strongly recommend it." When asked if the innovation had increased their crop yields and crop survival rate, 100 percent of women answered yes to both questions, while 82.2 percent of men answered that their yields either "increased" or "substantially increased," and 86.7 percent said their crop survival rates had increased after the innovation introduction.

All interview respondents reported hiring local neighbors to work on their fields at specific critical stages of the farming cycle. When asked how much they pay per labor day, three respondents reported paying different salaries based on the worker's gender, with female daily wages reported ranging from INR. 300 to 350 and male from INR. 350 to 450.

Comparison between latest Innovator Monitoring and Evaluation (M&E) and latest SWFF M&E

For four of the 50 respondents, a discrepancy exists between the 2016 and 2017 crop yields reported in 2019 when interviewed for this report and yields previously reported when visited by an AST evaluation team in 2016 and 2017. According to AST's local representative, field evaluations were conducted after the farmers had harvested their crop the years the innovation was used. The most striking example of this deviation is a farmer who, when interviewed by AST, reported a 2017 mung harvest of 55 kg/bigha. When asked again in 2019, he reported that his entire 2017 mung harvest was lost due to his crop failing to develop bean pods toward the end of its growth cycle. In all cases of deviations in reported crop yields, respondents reported a higher crop yield in 2016 or 2017 than in 2019, except in one case (Table 7).

TABLE 7: COMPARISON OF CROP YIELD REPORTS

INNOVATION USER	MUNG PER BIGHA (AST 2016/2017)	MUNG PER BIGHA (SWFF 2019)	PEARL MILLET PER BIGHA (AST 2016/2017)	PEARL MILLET PER BIGHA (SWFF 2019)
1	55 kg	0 kg	–	–
2	100 kg	50 kg	–	–
3	200 kg	150 kg	350 kg	400 kg
4	60 kg	30 kg	–	–

DISCUSSION

Usage/Availability

AST's portable treatment facilities were set up on farms throughout the villages involved in the innovation project. The vast majority of innovation users brought their own saved seeds to be treated with the fungi microbe solution. The local AST representative reported most of the seeds brought to the treatment events were of good quality, although sometimes bad seeds and accumulated micro-debris had to be removed before treatment.

Twenty-nine of the respondents (56 percent) used the innovation for more than one year, implying that the portable innovation treatment facilities have been arriving at a time and in an area available to them during several crop seasons. Of the 21 respondents (43 percent) who used the innovation during one crop season, four reported declines and one reported a significant decline in crop yield when using the innovation. Given their yield accounts, one might assume these respondents were not getting seeds treated for a second crop season. However, among the remaining 16 one-year users 15 reported a crop yield increase with innovation, and several said they wanted to get their seeds treated during one or more subsequent crop seasons. Unfortunately, on these occasions they were eithernot informed about the event or not able to attend on the particular day for seed treatments in their village.

Several respondents also mentioned the desire to receive advice on water-efficient agricultural practices in conjunction with the seed treatment events. One respondent said he considered the agricultural advice he received from innovation personnel as one of the main benefits of using the innovation.

Crop yield and survival

Forty-two of the respondents (84 percent) reported that they received either an "increase" or a "significant increase" in crop yields compared with when they were used untreated seeds. When asked to elaborate on the reasons for the yield increase when using the innovation, most indicated the innovation had lowered the crops' water demand, increased its resilience in severe drought and heat conditions, and enabled it to more efficiently convert fertilizers into plant growth.

When farmers asked for advice on appropriate agriculture practices and inputs using the innovation, AST recommended farmers continue to use the same procedures and inputs they used before the innovation. The fact that farmers did not have to spend energy and money on new agricultural techniques and inputs may be a contributing factor to farmer willingness to try the innovation.

It appears respondents took AST's advice. When asked about the use and spending on agriculture inputs before and after the innovation, none reported any changes in behavior before and after the innovation introduction. However, there was one substantial exception: the respondents who primarily used market seed before the innovation switched to using their own seeds from the previous year's harvest. The implication of the switch on these respondents' income is explained in the "Changes in income" section below.

Because 48 respondents use rainwater as their only source of irrigation, data collected cannot produce any reliable quantitative measurements on the amount of water consumed by crops prior to and during the use of the innovation. However, collected qualitative water consumption data shows that apart from the 68 percent that said that they did not know if their usage changed, 32 percent of respondents estimated or felt sure the innovation lowered their water consumption. Hence, it can be assumed that the innovation had a positive impact on crop water savings for the respondents, even though gathering quantitative data was outside the scope of this study.

The respondents who have experienced an increase in crop survival rate with BioEnsure treated crops are generally ascribing this increase to an increase in heat and drought resistance of the crops, as exemplified by the following quotes.

FARMERS REPORTING INCREASED CROP SURVIVAL RATE AS DUE TO BIOENSURE INNOVATION

"For me, the treated seeds have survived with only one major rainfall when other seeds died."

"In 2018, a low rainfall year, I was using the innovation, and I still got a good yield compared to what I am used to getting when using market seeds in similar conditions."

"During an unusually dry growing season innovation treated seeds survived while market seeds dried up."

Conversely, one respondent who reported lower crop survival rates of the BioEnsure treated crops ascribed it to lack of crop maturity, while another attributed it to slower crop growth rate than that of market seeds, as exemplified by the following quotes.

FARMERS REPORTING DECREASED CROP SURVIVAL RATE AS DUE TO BIOENSURE INNOVATION:

"Using market seeds, I have had higher growth rate than with innovation treated seeds. The growth of crop flowers and fruits was delayed with innovation treated seeds and due to increased temperatures the crop had to be cut prematurely to not risk drying out."

"Using the innovation I got no yield, this since the crop did not develop any pods when it was time for flowering."

The two reports of reduced crop growth rate are contrasted by another respondent's experience, as he explains, "The increased growth speed the innovation gave my plants makes for a shorter crop cycle and hence shorter time that the crops can be damaged by weather events and different pests." The narratives of reduced growth rates also were questioned by a local AST representative during a field study visit. This issue is discussed in detail in the section "Comparison of latest innovator M&E statistics with latest SWFF M&E statistics" below.

Aside from the two respondents experiencing changes in their crop growth rates while using the innovation (as quoted above), all other interviewed innovation users have not experienced any changes in crop development speed or harvest cycle length compared with crops that did not use the innovation.

Changes in income

Forty-three of 50 respondents (86 percent) reported using the innovation increased their family income. In reviewing the responses, two explanations to the income increase became apparent. The first is the "increase" or "significant increase" of crop yield reported by 38 users. This increase can be expected to result in significant income gains, especially since all reported growing mung which gives the best price of the region's crops. The second is the seeds inputs savings. Instead of buying market seeds, respondents used their own saved and treated seeds, resulting in lower production costs and higher profit margins. The second income increase explanation only applies to respondents switching from market seeds to saved seeds and not those already using their own seed.

Respondents achieving an income increase by using the innovation invested new revenues in several ways that, in the long run, are likely to deliver significant poverty reduction (Figure 9). The most obvious is expenditures to send and/or keep children in school, feed the family, and

improve farming capacity. In addition, while not as significant, reported investments on "house improvements" and "household activities" also may bring positive poverty reduction.

The six respondents not reporting an income increase said they had lower harvest yields than before using the innovation. Responses from four of these are discussed in depth in section "Comparison between latest Innovator Monitoring and Evaluation (M&E) and latest SWFF M&E" below.

It is beyond this study's scope to inquire into accurate reason(s) for reported crop yield declines. However, based on farming insights that were shared during interviews and field visits, it is clear that apart from the BioEnsure solution, many regional factors have the potential to affect crop yields. Examples include time of sowing and harvesting, quality of input seeds, wind direction and force, and rain frequency and timing during different crop cycle phases.

Gender differences

Four of the five female respondents live in households with both male and female family members (ranging from four to 12 family members), while one lives in a single household. Given the prevailing conservative nature of the Nagaur villages in the innovation project, it can be assumed that spouses, sons, or other male relatives de facto have the final word in terms of major household decisions and spending such as purchasing agricultural inputs. However, since females are equally engaged in agricultural work in Nagaur, both sexes can be considered equipped to give accurate answers regarding the innovation's impact on household farming activities.

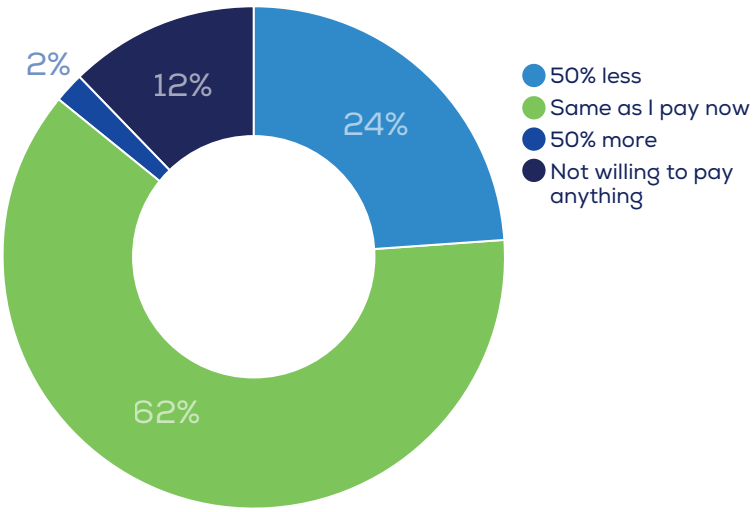
One reason why all female respondents reported the innovation increased crop yields and survival rates, while not all men reported this, may be that women in general are more focused on pragmatic ways of ensuring their children are well fed and receive a good education than on getting involved in village politics (the local AST representatives indicate village schisms exist between the village they belong to and some of the other innovation villages). Another plausible explanation is that the five female respondents might not be fully representative of the female innovation users group as a whole.

Affordability

When the innovation was first introduced in the Nagaur district in 2016, people who obtained seed treatments were not charged in an effort to spread the news of the innovation and its benefits as rapidly as possible through word of mouth marketing. Since 2017, innovation users have been paying INR. 50 per kilogram of innovation treated pearl millet seed and INR. 100 per kilogram of treated mung and bean seed. Four of the 50 respondents, deemed by the innovator to have exceptionally dire economic situations because they own land ranging from zero to five acres, were offered seed treatment at the discounted rate of INR. 30 per kilogram. However, one person in this group, a single household widow who did not own the eight acres of land she farms, elaborated on her willingness to pay for the innovation: "For me the investment that is needed to pay for the innovation is a considerable amount of money."

Twelve respondents (24 percent) claim they are willing to pay "50 percent less" than what they currently pay for the innovation (Figure 10). Some respondents might tend to underreport what they are actually willing to pay in hopes their answer will affect the innovation's future price. Because income data accuracy is considered low, comparing it with the price paid for the innovation would not provide useful insight into the prevalence of underreporting. However, this theory is supported by the fact that out of the 12 people in question three reported using the innovation for two years, three for three years, and one for four years. This recurring use raises the question of why someone would otherwise pay what they considered to be too much for the product repeatedly.

FIGURE 10: WILLINGNESS TO PAY FOR INNOVATION
N=50



Comparison of latest innovator M&E statistics with latest SWFF M&E statistics

When comparing the M&E yield data collected by AST in 2016 and 2017 in conjunction with harvest of innovation treated crops with that collected during the interviews, there was a response discrepancy in reported crop yield values of four respondents (Table 7). A possible explanation for the variation in reported yield could be that respondents had difficulty recalling exact crop yields or not confusing them with adjacent year yields since two to three years had passed between harvests and and the interviews.

In the case of a respondent who reported losing all yield due to his treated mung crop failing to develop bean pods, the probability of a memory slip about whether or not he used treated seeds at the time can be considered fairly low. As previously mentioned, the local AST representative strongly doubted the yield report accuracy, referring to AST's previously collected M&E statistics. Moreover, the representative pointed out that if the respondent's claim was correct, the respondent would have gone to the AST representatives to complain and demand a reimbursement for considerable loss in annual income. According to the AST representative, this did not occur.

Worth noting is that all four respondents with crop yield data discrepancies said during the interviews they "would not recommend" the innovation. Two reported their yield "declined" and one reported it had "substantially declined" using the innovation. Given the yield data discrepancies of these three respondents, if their recall of previous harvest seasons had blurred with time, it is possible their yields might not have declined as much as claimed.

CONCLUSION

AST's BioEnsure project in Nagaur aims to increase crop yields and help farmers adapt to increasingly frequent low-rainfall crop seasons by infusing crops with enhanced drought survival abilities. Using a survey of 50 innovation users, complemented by field observations, the field evaluator assessed the BioEnsure project's impact regarding its objective. This included user perceptions of the innovation and its effect on crop yield, crop survival rates and household income.

BioEnsure users have a very positive perception of the innovation, with 84 percent of interviewed users reporting they will continue using the innovation for at least five to 10 years. Women had slightly more positive perceptions than men; all interviewed women reported they plan to continue using the innovation and would recommend it to others.

The most frequently reported innovation benefit is an increased crop yield, both from farmers who previously sowed their own saved untreated seed and those who previously sowed market seed. The highest reported yield gain compared to saved untreated seed was 50 percent, while the highest compared to market seed was 30 percent. A few users reported crop yield declines, which may be reduced in the future by offering tailored farming advice in conjunction with seed treatment events.

Eighty-eight percent of respondents reported that using the innovation increased their crop survival rates. Clues to this increase might be found in farmers' stories of the ability of BioEnsure treated seeds to produce a good harvest even in less than normal rainfall years and in the prevailing notion among respondents that the innovation reduces crop water consumption.

Because very few respondents felt comfortable sharing income information, it is hard to draw comprehensive conclusions about the innovation's impact on overall incomes. However, when asked how the innovation affected household income 86 percent answered that, to various extents, it impacted their income in a positive way.

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ANNEX I

FARMER INFORMATION

NAME _____

AGE _____

DATE _____ TIME _____

GROUP INTERVIEW? ❏ Yes ❏ No

GROUP INTERVIEW NOTES

_____

_____

_____

HOW MANY FAMILY MEMBERS LIVE WITH YOU? _____

GENDER ❏ Male ❏ Female

WHAT IS YOUR PRIMARY OCCUPATION?

- ❏ Farming
- ❏ Wage Labor
- ❏ Seasonal Migrant Labor
- ❏ Small Enterprise
- ❏ Other: _____

DO YOU HAVE ANOTHER OCCUPATION?

- ❏ Farming
- ❏ Wage Labor
- ❏ Seasonal Migrant Labor
- ❏ Small Enterprise
- ❏ Other: _____

SIZE OF FARM (ACRES) _____

NAME OF VILLAGE _____

HOW MUCH LAND DO YOU OWN? _____

HOW LARGE IS YOUR FARM/PLOT?

- ❏ Large
- ❏ Medium
- ❏ Small
- ❏ Very Small

HOW MUCH IS LAND RENT? _____

OTHER LAND NOTES

_____

_____

_____

HOW LONG HAVE YOU BEEN USING ADAPTIVE SYMBIOTIC TECHNOLOGIES (AST)? _____

DID YOU PARTICIPATE IN AGRICULTURAL ACTIVITIES THIS YEAR? ❑ Yes ❑ No

HOW MANY MONTHS IS THE PRIMARY GROWING SEASON? _____

HOW MANY TIMES DO YOU HARVEST PER YEAR? _____

FARM INFORMATION

WHAT CROPS DO YOU GROW AS A RESULT OF THE INNOVATION? LIST FROM MOST IMPORTANT TO LEAST IMPORTANT:

1. _____

2. _____

3. _____

DID THE MOST IMPORTANT CROP BENEFIT FROM ADAPTIVE SYMBIOTIC TECHNOLOGIES (AST)?
❑ Yes ❑ No

DID THE SECOND MOST IMPORTANT CROP BENEFIT FROM ADAPTIVE SYMBIOTIC TECHNOLOGIES (AST)? ❑ Yes ❑ No

DID THE THIRD MOST IMPORTANT CROP BENEFIT FROM ADAPTIVE SYMBIOTIC TECHNOLOGIES (AST)? ❑ Yes ❑ No

WHAT IS THE WATER SOURCE FOR YOUR IRRIGATION OF CROPS?

- ❑ Own pond
- ❑ River
- ❑ Groundwater
- ❑ Innovation Source
- ❑ Other: _____

WHAT IS YOUR METHOD OF IRRIGATION?

- ❏ Drip feed
- ❏ Flooding
- ❏ Hand watering
- ❏ Rainfed
- ❏ Other: _____

HOW MUCH HAS YOUR WATER USAGE CHANGED SINCE USING ADAPTIVE SYMBIOTIC TECHNOLOGIES (AST), IF AT ALL? _____

_____

USING ADAPTIVE SYMBIOTIC TECHNOLOGIES (AST) HAS YOUR ACCESS TO WATER:

- ❏ Had no change
- ❏ Improved
- ❏ Fundamentally improved (Improved a lot)
- ❏ Other: _____

PREVIOUSLY GROWN CROPS: DID YOUR FARM PRODUCE DIFFERENT CROPS IN THE PAST THAT ARE NO LONGER GROWN HERE? IF SO, WHICH ONES? _____

_____

MASS OF PRODUCE: WHAT YIELDS DID YOU HAVE FOR EACH CROP YOU MENTIONED?

_____

_____

MASS OF PRODUCE 2: WHAT YIELDS DID YOU HAVE FOR YOUR CROPS BEFORE USING ADAPTIVE SYMBIOTIC TECHNOLOGIES (AST)? _____

_____

USING ADAPTIVE SYMBIOTIC TECHNOLOGIES (AST) HAVE YOU, FOR EACH CROP:

- ❏ Used more water
- ❏ Had no change in water use
- ❏ Used less water
- ❏ Other: _____

USING ADAPTIVE SYMBIOTIC TECHNOLOGIES (AST) HAVE YOUR CROP YIELDS (ASK FOR EACH CROP):

- ❏ Declined
- ❏ Remained the same
- ❏ Increased
- ❏ Substantially increased

IS THERE A DIFFERENCE IN THE SURVIVAL RATES OF YOUR CROPS DUE TO ADAPTIVE SYMBIOTIC TECHNOLOGIES (AST)? ❑ Yes ❑ No

HOW MUCH OF YOUR PRODUCE DID YOU CONSUME IN YOUR HOUSEHOLD? (PERCENTAGE – NOTE IF DIFFERENT FOR EACH CROP) _____

_____

HOW MUCH OF EACH OF THE FOLLOWING INPUTS DID YOU USE BEFORE ADAPTIVE SYMBIOTIC TECHNOLOGIES (AST)?

FERTILIZER _____ (KG)
PESTICIDE _____ (KG)
HERBICIDE _____ (L)
CHARCOAL _____ (KG)
WATER _____ (TOTAL)
LABOR _____ (DAYS)
OTHER _____

HOW MUCH DID YOU SPEND ON EACH OF THE FOLLOWING INPUTS BEFORE ADAPTIVE SYMBIOTIC TECHNOLOGIES (AST)?

FERTILIZER _____ (KG)
PESTICIDE _____ (KG)
HERBICIDE _____ (L)
CHARCOAL _____ (KG)
WATER _____ (TOTAL)
LABOR _____ (DAYS)
OTHER _____

HOW MUCH OF EACH OF THE FOLLOWING INPUTS DO YOU USE AFTER ADAPTIVE SYMBIOTIC TECHNOLOGIES (AST)?

FERTILIZER _____ (KG)
PESTICIDE _____ (KG)
HERBICIDE _____ (L)
CHARCOAL _____ (KG)
WATER _____ (TOTAL)
LABOR _____ (DAYS)
OTHER _____

HOW MUCH DID YOU SPEND ON THE FOLLOWING INPUTS AFTER ADAPTIVE SYMBIOTIC TECHNOLOGIES (AST)?

FERTILIZER _____ (KG)
PESTICIDE _____ (KG)
HERBICIDE _____ (L)
CHARCOAL _____ (KG)
WATER _____ (TOTAL)
LABOR _____ (DAYS)
OTHER _____

HOW MUCH DID YOU SPEND ON EQUIPMENT BEFORE AND AFTER ADAPTIVE SYMBIOTIC TECHNOLOGIES (AST)? _____

_____

HOW MUCH DID YOU SPEND ON TRANSPORT AND STORAGE BEFORE AND AFTER ADAPTIVE SYMBIOTIC TECHNOLOGIES (AST)? _____

DO YOU HAVE PROBLEMS FINDING A MARKET TO SELL YOUR CROPS IN? ❑ Yes ❑ No
PLEASE EXPLAIN. _____

_____

DO YOU HAVE PROBLEMS GETTING YOUR CROPS TO THE MARKET? ❑ Yes ❑ No
PLEASE EXPLAIN. _____

_____

OTHER FARM NOTES (OPTIONAL).

_____

_____

_____

INCOME AND EXPENDITURES

WHAT IS YOUR ANNUAL HOUSEHOLD INCOME? _____

HOW MUCH INCOME DID YOU MAKE BEFORE ADAPTIVE SYMBIOTIC TECHNOLOGIES (AST)? _____
AFTER ADAPTIVE SYMBIOTIC TECHNOLOGIES (AST)? _____

HAS ADAPTIVE SYMBIOTIC TECHNOLOGIES (AST) IMPROVED YOUR FAMILY INCOME? _____

WHAT PERCENTAGE OF YOUR INCOME DO YOU GET FROM NON-FARM SOURCES? _____

HOW MUCH PRODUCE DID YOU SELL FOR EACH OF YOUR CROPS IN THE LAST SEASON AND THE LAST YEAR? _____

_____

WHAT IS THE PRICE PER KILO YOU RECEIVED FOR EACH OF YOUR CROPS FOR THE LAST SEASON?

_____

_____

USING ADAPTIVE SYMBIOTIC TECHNOLOGIES (AST) HAS YOUR ACCESS TO CREDIT:

- ❏ Not improved
- ❏ Improved
- ❏ Improved and have been able to repay over a short period

HOW DO YOU CURRENTLY FINANCE AGRICULTURAL ACTIVITIES?

- ❏ Own savings
- ❏ Credit and savings scheme
- ❏ Other credit

HOW MUCH DO YOU PAY FOR ADAPTIVE SYMBIOTIC TECHNOLOGIES (AST)? _____

HOW MUCH ARE YOU WILLING TO PAY FOR ADAPTIVE SYMBIOTIC TECHNOLOGIES (AST)?

- ❏ Nothing
- ❏ ADAPTIVE SYMBIOTIC TECHNOLOGIES (AST) is free
- ❏ The same as what I pay now
- ❏ 50% less
- ❏ 50% more
- ❏ Other: _____

HOW HAVE YOU SPENT YOUR NEW INCOME?

- ❏ N/A (if no new income)
- ❏ Send children to school or keep children in school
- ❏ Social functions (like weddings)
- ❏ Investment in farming
- ❏ Improving house
- ❏ Other: _____

OTHER INCOME NOTES (OPTIONAL)

_____

_____

_____

PERCEPTIONS OF ADAPTIVE SYMBIOTIC TECHNOLOGIES (AST)

WILL YOU USE ADAPTIVE SYMBIOTIC TECHNOLOGIES (AST) IN THE FUTURE (5 TO 10 YEARS)?
❏ Yes ❏ No

WHY? _____

_____

HOW, IF AT ALL, HAVE YOU CHANGED YOUR FARMING PRACTICES DUE TO ADAPTIVE SYMBIOTIC TECHNOLOGIES (AST)?

- ❏ No change
- ❏ Introduced new crops
- ❏ Changed irrigation system
- ❏ Reduced water usage
- ❏ It helps me decide when to plant
- ❏ It helps me decide which crops to plant

HAVE YOU FACED ANY DIFFICULTIES OR PROBLEMS USING ADAPTIVE SYMBIOTIC TECHNOLOGIES (AST)? ❏ Yes ❏ No

HOW CAN ADAPTIVE SYMBIOTIC TECHNOLOGIES (AST) BE IMPROVED? _____

_____

HOW DID YOU HEAR ABOUT ADAPTIVE SYMBIOTIC TECHNOLOGIES (AST)?

- ❏ Wealthy farmer
- ❏ Neighbor
- ❏ Innovation personnel
- ❏ Extension worker
- ❏ Other: _____

WHAT FACTORS INFLUENCED YOU TO TRY ADAPTIVE SYMBIOTIC TECHNOLOGIES (AST)?

- ❏ Demonstration from neighbor's farm
- ❏ Innovation is free from extension services
- ❏ No alternative water source
- ❏ Other: _____

DO YOU SHARE YOUR KNOWLEDGE SKILLS FROM ADAPTIVE SYMBIOTIC TECHNOLOGIES (AST) WITH OTHERS? ❏ Yes ❏ No

IF SO, HOW? _____

_____

_____

WHAT DO YOU FEEL ARE THE BENEFITS OF ADAPTIVE SYMBIOTIC TECHNOLOGIES (AST)? _____

_____

_____

HAVE YOU HEARD ABOUT CLIMATIC VARIATION? HAVE CHANGES IN RAINFALL OR TEMPERATURE AFFECTED YOUR FARMING PRACTICES OR CROP YIELDS COMPARED TO YOUR HISTORICAL RAINY/DRY SEASON PERIODS? ❏ Yes ❏ No

PLEASE SPECIFY HOW. _____

_____

_____

HOW HAS ADAPTIVE SYMBIOTIC TECHNOLOGIES (AST) HELPED YOU? PLEASE RANK THE TOP 3 AND EXPLAIN POSITIVES/NEGATIVES.

☐ Makes water reusable _____

☐ Helps women farmers as well as men _____

☐ They made a special effort to include women farmers _____

☐ Helps in producing more of our most important crop _____

☐ Increases my yield through timely forecasts _____

☐ Helps by lowering cost of inputs _____

☐ Improves health and strength of livestock _____

☐ Helps reduce labor _____

☐ Reduces crop wastage _____

☐ Helps me decide when to plant _____

☐ Helps me decide which crops to plant _____

☐ Other: _____

WOULD YOU RECOMMEND ADAPTIVE SYMBIOTIC TECHNOLOGIES (AST)?

❏ No
❏ Yes
❏ Yes, would strongly recommend

ARE THERE NEGATIVE IMPACTS FROM ADAPTIVE SYMBIOTIC TECHNOLOGIES (AST) IN THE COMMUNITY? ❏ Yes ❏ No

PLEASE EXPLAIN IF YES. _____

_____

_____

IF THERE HAVE BEEN ANY NEGATIVE IMPACTS, HAVE EFFORTS BEEN MADE TO RESOLVE THEM?
❏ Yes ❏ No

EXPLAIN. _____

_____

_____

OTHER

INCOME/POVERTY NOTES

GENDER OBSERVATIONS

QUESTIONS/REQUESTS

OTHER NOTES

SECURING
WATER
FOR FOOD:
A GRAND CHALLENGE
FOR DEVELOPMENT

Securing Water for Food has sourced and invested in a portfolio of innovative solutions that aim to help farmers use water more efficiently and effectively, improve water storage for lean times, and remove salt from water to make more food. Our cohort of innovators are helping people in 35 low-resource countries with tools they need to produce more food with less water.

To learn more about Securing Water for Food,
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