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- ▶ **Results of pilot trials on greenhouse productivity and working condition with 12 selected farmers in Akkar and the Bekaa**

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working condition with 12
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the Bekaa**

► Foreword

This report entitled: “Results of pilot trials on greenhouse productivity and working conditions with 12 selected farmers in Akkar and the Bekaa” was developed by the International Labour Organization (ILO) under the “Partnership for improving prospects for forcibly displaced persons and host communities,” also known as PROSPECTS, which is supported by the Government of the Netherlands.

The PROSPECTS global programme is a four-year partnership between the Netherlands, the ILO, the International Finance Corporation (IFC), the UN Refugee Agency (UNHCR), the UN Children’s Fund (UNICEF) and the World Bank, which operates in eight countries across the East and the Horn of Africa and the Middle East to support education, employment and protection in the context of forced displacement. In Lebanon, the partnership focuses on reducing multidimensional vulnerabilities and increasing social stability for both Syrian refugees and Lebanese host communities, under the three main pillars of education and learning; employment with dignity; and protection and inclusion.

Within PROSPECTS, ILO is taking action to increase productivity and improve working conditions in Lebanon’s horticulture sector with a view to creating more and better jobs in agriculture for both Lebanese host communities and Syrian refugees. As part of a larger intervention strategy, on-farm trials with 12 selected farmers were launched to test the impact of modern multi-span greenhouse designs on productivity, working conditions and incomes. This report summarizes results and data collected on the 12 farms between October 2020 and September 2021.

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1. Context

Within the larger “Partnership for improving Prospects for forcibly displaced persons and host communities” (PROSPECTS), ILO is taking action to increase productivity and improve working conditions in Lebanon’s horticulture sector with a view to creating more and better jobs in agriculture for both Lebanese host communities and Syrian refugees. As part of a larger intervention strategy, a first pilot project has been launched to promote uptake of more modern greenhouse technologies amongst small and medium farmers. As a first step, on-farm trials were conducted in close collaboration with suppliers of greenhouses and interested farmers to test the impact of different selected modern greenhouse designs on productivity, working conditions and incomes compared to traditional designs, and collect data that can be used to develop information strategies for farmers.

The objectives of these trials were two-fold. They served a) as ‘demo-plots’ to convince farmers of the benefits of upgrading greenhouses, and b) to generate data on the impact of various greenhouse designs on productivity, incomes and working conditions of horticulture farms which can be used to launch information campaigns for farmers.

Trials were launched in the two main project regions, Akkar and Bekaa with a total of 12 participating farms, 6 in Akkar and 6 in the Bekaa region. For the main crops produced by most farmers, tomatoes and cucumbers, agricultural season differ in both regions. In Akkar, farmers have two agricultural seasons for these main crops, starting between September and November, and February/March respectively. In the Bekaa, tomatoes and cucumber can only be produced in the summer season starting in March, with the winter season being used by most farmers to produce lettuce and cabbages. Consequently, trials were launched in October 2020 in Akkar, and in March 2021 in the Bekaa.

2. Objectives of the greenhouse productivity trials

The vast majority of horticulture farmers is relying on basic traditional methods using simple plastic span greenhouses to produce. Basic plastic spans structures with their rounded designs make it impossible to use space in the most efficient manner and inevitably result in a certain percentage of lower-grade produce. They also provide sub-optimal conditions in greenhouses due to heat, bad ventilation and increased exposure to insects that not only lead to low productivity, but also negatively impact working conditions of greenhouse workers.

More modern and productive greenhouse designs are available on the Lebanese market and studies have indicated that upgrading to more productive greenhouse technologies would result in significant productivity increase and thus ultimately increase farmers' incomes while also improving working conditions for laborers in greenhouses. Upgrading to more modern greenhouses also has positive effects on the environment as production in modern greenhouses optimizes water usage and requires fewer pesticide sprayings.

Interviews with farmers, greenhouse suppliers and experts point to two main constraints that are currently inhibiting investments into more productive greenhouse technologies:

1. Farmers are not aware of or do not believe in the productivity benefits of modern greenhouse designs and technologies, and
2. Farmers are no longer able to buy greenhouses and other inputs on credit, and are hence unable to afford greenhouses

While the lack of awareness and access to clear information about the benefits of different greenhouse models is the result of more longstanding issues in the system, the inability of farmers to obtain credits or other sources of finance is a more recent phenomenon brought about by the economic and financial crises. Farmers always had very limited access to official loans and financial services offered by banks, but traditionally relied on informal credit extended by either input suppliers or wholesalers that enables them to buy greenhouses or other inputs and pay for these in tranches at a later stage.

However, in light of the massive exchange rate fluctuations, official credit lines from banks being frozen and Covid-19 disrupting supply chains, suppliers have stopped extending credit to farmers, making it nearly impossible for farmers to purchase inputs. While the programme is in the current situation unable to solve the wider issues related to the financial system, it will seek to forge partnerships with relevant entities to extend much-needed credit lines to farmers. This will likely involve credit guarantee schemes aimed to de-risk investments of selected entities that would benefit farmers and help them invest in modern greenhouses.

While access to credit and other financing mechanisms are a major constraint to investments in the sector, an issue exists in parallel with information and advice on the benefits of modern greenhouses. Many farmers are vaguely aware that more modern greenhouses exist, but do not know about the specific benefits in terms of productivity and revenue increases that can be achieved by upgrading greenhouses. A survey with 200 farmers in Akkar and the Bekaa has confirmed that only 18% of interviewed farmers in the Bekaa and 0% of surveyed farmers in Akkar claim to have received information on modern greenhouses in the past 12 months. Whenever farmers did receive information, this usually pertained to basic information on the size and characteristics of modern greenhouses. None of the interviewed farmers mentioned specific benefits in terms of increased productivity and revenues.

The programme thus aims to tackle both constraints simultaneously and work with local partners to explore ways to extend both necessary information and advice, as well as credit lines to farmers. As a

first step, the programme thus decided to set up on-farm trial stations in close collaboration with interested farmers and suppliers of greenhouses to test the impact of different selected modern greenhouse designs on productivity, working conditions and incomes compared to traditional designs, and collect data that can be used to develop information strategies for farmers. The trials thus served two objectives at the same time. It will:

2.1. Serve as ‘demo-plots’ to convince farmers of the benefits of upgrading greenhouses

The project selected farmers that are well-respected within their respective communities for participation in the trials. Farmers that participate were then encouraged to spread the word on results of the trial within their communities. Spreading the news through participating farmers in communities of different regions of Akkar and Bekaa should encourage other farmers to look into options to upgrade their greenhouses as well (subject to credit or financing mechanisms). While all greenhouse suppliers reportedly run demo-plots to test new greenhouses and other inputs, running trials on real-life farms with the involvement of farmers can have important advantages. On-farm trials that test new greenhouses under ‘real life’ conditions are more likely to convince farmers, in particular those that are traditionally skeptical towards advice provided by the public sector or private sector companies.

2.2. Generate data on the impact of various greenhouse designs on productivity, incomes and working conditions of horticulture farms

Perhaps most importantly, the on-farm trials aimed to generate data on the exact benefits of different greenhouse design on productivity, incomes and working conditions with a view to using the collected data to launch large-scale information campaigns. Participating farmers were asked to upgrade one of their greenhouses to a more productive greenhouse and then collect data on yields, production costs, working conditions and profits obtained in both the traditional greenhouse and the modern greenhouse. The collected data shed light on exact benefits of the different greenhouse designs and can then be used to work with greenhouse suppliers and other relevant actors to develop an information campaign to help farmers understand the advantages of different greenhouse designs and their benefits in terms of productivity, incomes and working conditions.

3. Design of the greenhouse productivity trials

On-farm trials were designed to collect comparative data on productivity, incomes and working conditions in traditional and upgraded greenhouse models. To this end, farmers located in different locations representing different microclimates of Akkar and Bekaa were selected and asked to upgrade one or more greenhouses. Trials tested different mid-range non-computerized greenhouse designs from different greenhouse suppliers and collected data on a variety of indicators related to productivity, incomes and working conditions.

Due to the different micro-climates in the different regions of Lebanon, greenhouse designs tested in Akkar and Bekaa differed. Specifically, greenhouse designs tested in Bekaa had to be shaped differently so as to withhold pressure from snowfalls during the winter season. In addition, trials needed to take into consideration differences in the seasonality of both regions. Hence, trials in Akkar were set up to start in mid-September to make use of the autumn/winter season, while trials in Bekaa started in March in time for the spring/summer season. In Akkar on-farm trials thus ran for one year and captured several seasons, while in the Bekaa only one season was covered.

Based on discussions with the suppliers and experts, 3 different greenhouse designs were selected to be tested on farms. Greenhouse designs that were tested are so-called 'multi-span' greenhouses. Specifically, the trials tested non-computerized mid-range options that are well-adapted to conditions and needs of the Lebanese market, and less expensive than fully computerized high-end designs. These mid-range options do however represent a significant improvement to traditional single span greenhouses as they provide several benefits, including:

- High standing side walls: Traditional greenhouses have a round shape (see pictures below) that limit the height of plants at the outer edges. Multi-span greenhouses have high side walls that allow for **optimization of space** and also improve the quality of the vegetables produced. The increased height also allows for **better ventilation and improved climate** that should result in higher yield per m².
- Side opening with insect nets: Side walls of the multi-span can be manually opened for better ventilation but are equipped with insect nets for **better protection from insects and pests**. This results in higher productivity as plants stay healthy while reducing the need to spray harmful and expensive pesticides.
- Double entrance doors: double entrance doors provide **better protection against insects and pest** and thus further improve plant health and reduce the need to spray pesticides.
- Bi-tunnel greenhouses: Traditional greenhouses are essentially 'tunnels' (see picture below) and having several tunnels means leaving a space between these tunnels. This space of 2-3 meters is usually lost for effective production. Multi-span greenhouses on the other hand are greenhouses where several 'tunnels' are connected to each other. This means that **no land is wasted**, and all land can be used for greenhouse production.

► **Traditional greenhouses (left) vs multi-span greenhouse (right)**



Together with the greenhouse suppliers and the greenhouse experts, technical specifications of the trial were discussed and set up in a way to allow for generation of data on the impact of different greenhouse designs on productivity, incomes and working conditions. Generating such data required farmers to produce the same crop and apply the same production practices in traditional and upgraded greenhouses so as to ensure comparability of data.

On each farm, farmers applied the same practices in two traditional greenhouses (usually 2x 332 m²) and in one 'bi-tunnel' multi-span greenhouse (664m²). Farmers were free to produce either tomatoes or cucumbers in these structures, under the condition that the same varieties and production practices will be used in the both the traditional and the modern structures.

Expert consultants were recruited by the project in both regions to supervise farmers and ensure they correctly collect and record all required data. Next to information on varieties and inputs used, and the number of working hours spend in each greenhouse, farmers were asked to collect data on:

- Yields: yields were usually recorded in Kg for each greenhouse when crops were harvested
- Sales: Farmers were asked to sell produce from the traditional and the modern greenhouse separately at the market and record the prices obtained for each (in LBP) as well as the percentage of Grade A and Grade B produce obtained from each greenhouse

Additional to the records, data loggers that were installed in all greenhouses to continuously record climate including heat and humidity in both types of greenhouses. Following each season, the expert consultants were asked to compile and analyze the data, and calculate three main measures for the traditional and the multi-span greenhouses:

- **Yield per m² (total yield per greenhouse in Kg / greenhouse area in m²)** was used as the main measure for pure productivity. By the dividing the total yield (Kg) obtained per greenhouse by the area that the greenhouse occupies, the project team was able to account for possible variations in the size of different greenhouses
- **Revenue per m² (total revenue per greenhouse in LBP / greenhouse area in m²)** was used as a main measure calculate revenue gains in the multi-span greenhouses. Just as for yield per m², dividing the total revenue obtained by the area the greenhouse occupies, allows to account for variations in the size of the greenhouses. Due to the substantial

fluctuations in the LBP/USD exchange rate and the prices of vegetables, it is difficult to compare revenues per m² across time and across the different seasons. However, it does still represent a solid measure to capture differences in revenues between traditional and multi-span structures on the same farm and during the same season.

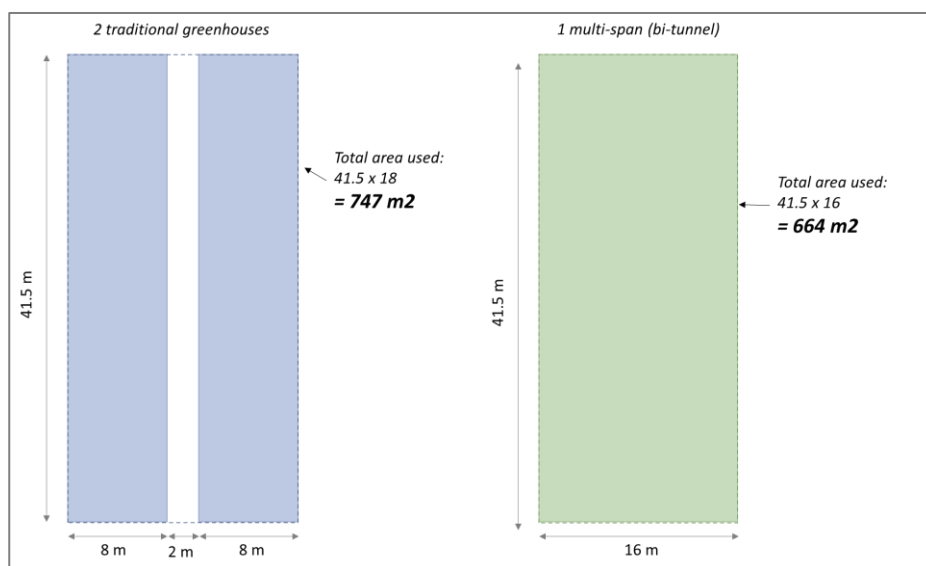
- **Adjusted revenue per m² (total revenue per greenhouse in LBP / land needed in m²)**
was used as an additional measure to calculate real revenue gains after accounting for the additional space between traditional tunnels that is lost for production. As outlined above, traditional tunnels are built in a way that require a space of 2-3 meters between two single tunnels. Multi-span greenhouses on the other hand consist of two or more tunnel that are connected to each other (see pictures below). To account for the lost land when calculating revenue gains, revenues/m² were calculated, but using the total land used including the space between tunnels, instead of the area the greenhouse occupies (see diagram below). For the sake of the calculation, a space of 2m between the two tunnels was assumed.

► **Traditional tunnels with space between tunnels (left) vs multi-span without space (right)**



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► **Total land area used by two traditional tunnels vs one bi-tunnel**



4. Selection of participating farmers

In order to convince a maximum number of farmers in the region of the benefits of modern greenhouses, participating farmers were encouraged to spread the word and inform other farmers in their respective communities of their experience. To this end, it was important to select farmers that are well respected within their respective communities for participation in the trials. The project team also focused on selecting farmers located in different geographical sub-regions of Akkar and Bekaa, and be able to calculate costs and benefits of different production techniques in order to track changes and ensure that data collected is solid.

The following criteria were thus elaborated to select the 12 farmers.

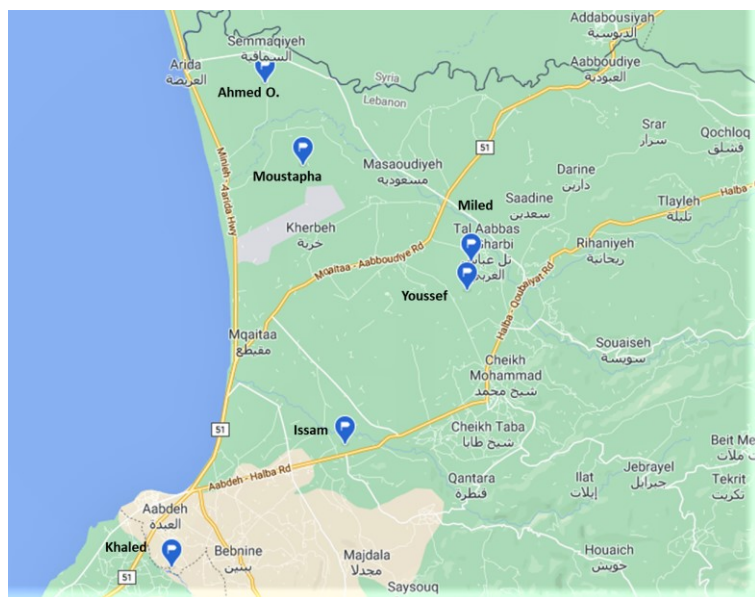
Size of farm:	Farmer should have a farm in Akkar with between 10 and 100 greenhouses. Preference is given to small-holder farmers
Willingness:	Farmers should be willing to upgrade one of the greenhouses and be able and willing to collect data on productivity, incomes, working conditions in both the traditional, and the upgraded greenhouses
Literacy:	Farmers should be literate and have experience in the calculation of production costs and profits so as to be able to record data
Status and reputation:	Farmers should be well respected and well connected within their local community, and ready to allow for visits from other farmers.
Geographical distribution:	Selected farmers should be equally distributed across different sub-regions and micro-climates of Akkar and Bekaa
Other considerations:	The project will give preference to women farmers, farmers that currently do not benefit from donor support and farmers that employ Syrian workers and/or women on their farms.

Based on these criteria, the following 12 farmers were selected for participation in the trial:

Name	Number of greenhouses	Number of permanent workers
Akkar:		
Youssef	70	30
Issam	100	20 + 5 family members
Ahmed O.	21	7
Milad	12	4
Khaled	30	19
Souhaib	140	25
Bekaa:		
Hanna	20	5
Omar	41	15
Wadih	12	Family
Ahmed H.	7	6
Kassem	25	10
Yasser	35	17

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► Map of geographic distribution of participating farmers in Akkar



► Map of geographic distribution of participating farmers across the Bekaa

(Note: greenhouse production is only possible around Zahle and Baalbek due to climate considerations)



5. Results of productivity trials

5.1. Productivity and revenue gains

Throughout the year, data has been collected on the 12 farms on production practices, costs, yields, revenues and profits in both the traditional and the modern greenhouses. Care has been taken to apply the production practices in both types of greenhouses, so as to ensure that data on production costs, yields and revenues are comparable.

Results of the productivity trials in Akkar and the Bekaa have surpassed expectations of the project team. Prior research of the possible benefits has estimated the potential productivity increases that could be achieved through these modern greenhouses at 30-40%. Based on data collected on the 12 farms, revenues in the modern greenhouses in Akkar increased by an average of 60.5%, and an average of 36.3% in the Bekaa. However, these averages hide important differences between cucumber and tomato production and do not yet include reduced production costs nor revenue increases that can be obtained from using available land to the fullest.

The revenue gain that can be obtained in the multi-span greenhouses is a result of different factors that are outlined in more detail below. A table with detailed overview of the data can be found on pages 12-13.

a. Productivity benefits (yield/m²)

Pure productivity as measured by yield/m² increased in the multi-span due to four factors:

1. better climate in the multi-span greenhouses (humidity, heat, ventilation, etc.) that allow for more vigorous and productive plants
2. better protection of plants against pests and diseases that reduce productivity due to nets installed on side walls and doors
3. possibilities to have taller plants, specifically at the inside edge of the structures, due to higher side walls
4. possibilities to extend the season in the multi-span due to extended life span of plants. This means that plants in the multi-span are still producing quality crops at a time when the plants in the traditional greenhouse have stopped producing due to high heat

Importantly, differences in pure productivity have been found to be substantially higher for cucumbers than for tomatoes, possibly because cucumbers are more sensitive to climate conditions. **Yield increases for tomato averaged 20.4%** (18% in Akkar and 23% in the Bekaa), while astonishingly, **yield increases for cucumbers averaged 66.2%** (80.5% in Akkar and 45.9% in the Bekaa).

These yield increases, particularly for cucumber, mask important differences between farmers and range from an increase of 'only' 17% to yield increases of over 235%. Several farmers were able to obtain yields in the multi-span that were more than 150% higher than in the traditional structure because pests and diseases had ravaged plants in the traditional structure and much less so in the multi-span. At first, the project team considered these incidences to be outliers and potentially not representative of average possible yield increases. However, across seasons, this scenario kept reoccurring on several farms (see results of individual farmers in sections 3 and 4). The project team thus considered that these substantive differences in yield are a direct result of better protection of plants in multi-spans, and thus should be considered as part of the trial results.

b. Improved quality of crops

Crops in the multi-span were found to be of higher quality and size than those in the traditional structures. This often translated to higher prices obtained for the crops produced in the multi-span, thus increasing revenues obtained from the multi-span production. However, not all farmers were able to obtain higher prices for their products at all times despite apparent quality differences. Whether or not higher prices were obtained depends on the specific timing of sales, the geographic location and the specific wholesale market or buyer farmers sell to, and possibly also on personal relations and negotiating power of the farmer in question.

It should also be clearly noted that revenues gains were likely underestimated, as some farmers did not clearly separate crops from the different structures when selling these on the market, as instructed. Rather, recognizing the better quality of produce from the multi-span, some farmers chose to place the good quality crops from multi-span greenhouses on top of boxes filled crops from traditional structures, so as to try and obtain higher prices for all produced crops. This practice likely led to significant underestimations of revenue differences

Nevertheless, **revenue increases for tomatoes averaged 24.7%** (26.3% in Akkar and 24.1% in the Bekaa), while **revenue increases from cucumbers averaged 74.7%** (96% in Akkar and 54.3% in the Bekaa).

c. Optimization of land use for production

As previously mentioned, traditional tunnels require space between two single tunnels while multi-span greenhouses consist of two tunnels (bi-tunnel) or more tunnels (multi-span) that are connected to each other. These thus provide the possibility to use all the land for production without leaving space between tunnels that cannot effectively be used for production.

When accounting for the additional land used between the tunnels¹, revenue gains obtained in the multi-span increase substantially. **Adjusted revenue increases obtained for tomatoes average 39.2%** (42.1% in Akkar and 38.1% in the Bekaa), while **adjusted revenue increases from cucumbers averaged 96.6%** (120.9% in Akkar and 73.6% in the Bekaa).

For the purpose of calculations, it was assumed that farmers leave a space of 2 meters between the tunnels. As some farmers leave more than 2 meters between tunnels, it can be assumed that real revenue gains through better optimisation of land are likely higher than those calculated here.

¹ In order to account for the lost land when calculating revenue gains, revenues/m² are calculated, but using the total land used including the space between tunnels, instead of greenhouse sizes (total revenue/m² land used)

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► **Table: Overview of productivity and revenue increases per crop and region for cucumber**

CUCUMBER											
Yield (Kg/m2)				Revenues (LBP/m2 of greenhouse)				Adjusted revenues (LBP/m2 of land used)			
	Trad	Modern	Difference		Trad	Modern	Difference		Trad	Modern	Difference
Baalbeck				Baalbeck				Baalbeck			
Ahmed	14.06	24.5	74.2	Ahmed	77,087	138,768	80.0	Ahmed	68,522	138,768	102.5
Omar	12.29	16.05	30.6	Omar	62,852	92,139	46.6	Omar	55,868	92,139	64.9
Wadi	6.90	7.98	15.7	Wadi	41,727	49,453	18.5	Wadi	37,090	49,453	33.3
Total Baalbeck	33.25	48.5	45.9	Total Baalbeck	181,666	280,360	54.3	Total Baalbeck	161,481	280,361	73.6
Akkar				Akkar				Akkar			
Youssuf (Winter)	5.71	8.25	44.4	Youssuf (Winter)	20,515	30,376	48.1	Youssuf (Winter)	17,961	30,376	69.1
Youssuf (Summer)	3.21	10.8	235.2	Youssuf (Summer)	19,702	69,917	254.9	Youssuf (Summer)	17,513	69,917	299.2
Souhaib (Winter)	6.54	7.64	16.9	Souhaib (Winter)	19,349	22,543	16.5	Souhaib (Winter)	17,219	22,543	30.9
Souhaib (Summer)	0.92	2.33	153.3	Souhaib (Summer)	3,256	8,333	155.9	Souhaib (Summer)	2,898	8,333	187.5
Issam (Winter)	3.74	9.78	161.9	Issam (Winter)	11,306	36,489	222.7	Issam (Winter)	10,050	36,489	263.1
Issam (Summer)	4.73	7.29	54.2	Issam (Summer)	23,054	35,575	54.3	Issam (Summer)	20,492	35,575	73.6
Khaled (Extended)	22.15	38.78	75.1	Khaled (Extended)	75,657	135,580	79.2	Khaled (Extended)	67,251	135,580	101.6
Total Akkar	47.0	84.8	80.5	Total Akkar	172,839	338,813	96.0	Total Akkar	153,385	338,813	120.9
National				National				National			
Total Akkar + Bekaa	80.24	133.35	66.2	Total Akkar + Bekaa	354,505	619,173	74.7	Total Akkar + Bekaa	314,865	619,174	96.6

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► Table: Overview of productivity and revenue increases per crop and region for tomato

TOMATO											
Yield (Kg/m2)				Revenues (LBP/m2 of greenhouse)				Adjusted revenues (LBP/m2 of land used)			
	Trad	Modern	Difference		Trad	Modern	Difference		Trad	Modern	Difference
Baalbeck				Baalbeck				Baalbeck			
Kassem	18.80	23.02	22.4	Kassem	163,592	201,495	23.2	Kassem	145,415	201,495	38.6
Hanna	8.98	11.50	28.0	Hanna	68,904	88,541	28.5	Hanna	61,248	84,827	38.5
Yasser	8.63	10.26	18.9	Yasser	46,574	56,283	20.8	Yasser	41,399	56,283	36.0
Total Baalbeck	36.411	44.8	23.0	Total Baalbeck	279,070	346,319	24.1	Total Baalbeck	248,062	342,605	38.1
Akkar				Akkar				Akkar			
Issam (Spring)	9.79	12.05	23.1	Issam (Spring)	51,657	63,630	23.2	Issam (Spring)	45,917	63,630	38.6
Ahmed H. (Fall)	8.27	8.74	5.6	Ahmed H. (Fall)	2,575	2,824	9.7	Ahmed H. (Fall)	2,289	2,824	23.4
Miled (Winter)	20.08	23.70	18.0	Miled (Winter)	41,939	50,066	19.4	Miled (Winter)	37,279	50,066	34.3
Miled (Fall)	0.7	1.3	100.0	Miled (Fall)	6,619	13,306	101.0	Miled (Fall)	5,884	13,306	126.2
Total Akkar	38.8	45.8	18.0	Total Akkar	102,790	129,826	26.3	Total Akkar	91,368	129,825	42.1
Total Akkar + Bekaa	75.21	90.57	20.4	Total Akkar + Bekaa	381,860	476,145	24.7	Total Akkar + Bekaa	339,430	472,430	39.2

5.2. Other benefits

Next to the benefits in terms of **increased yields and revenues** outlined above, upgrading structures to multi-span greenhouses hold multiple other benefits that could not be quantified for this trial. An important advantage of multi-span greenhouses is the fact that it provides **better protection from pests and diseases** as all opening are covered with nets. Since plants are naturally better protected, fewer pesticide sprayings are needed to protect plants. This constitutes an important advantage as expenses for pesticides are an important part of production costs. Reducing the number of pesticide spraying thus has the potential to lower production costs substantially.

However, it was important for this trial to compare differences resulting from the different structures only, and farmers were thus instructed to keep all other production practices constant. Hence, the same varieties were planted in the traditional and modern greenhouses and workers applied the same amounts of fertilizers and pesticides in the same frequency. The potential reduction in production costs by reducing the number of pesticide sprayings could therefore not be quantified with this trial. Nevertheless, experts agree that such potential exists, and one participating farmer admitted to spraying fewer pesticides in the modern greenhouse structure despite the instructions provided, as he simply did not want to waste money for expenses not needed.

Another important benefit of multi-span greenhouses is the **possibility to extend seasons** beyond what is possible in traditional structures. Due to improved climate in the structures and better protection from pests, plants in the multi-span tend to produce longer, enabling farmers to harvest at a time when plants in traditional greenhouses have stopped producing. These harvests outside of peak harvest times often enable farmers to obtain higher than average prices for crops on the market.

As the trials aimed to test modern greenhouses under real-life conditions, farmers were free to manage cropping seasons and crops planted as they saw fit. Hence, some farmers seized the opportunity to extend seasons which usually resulted in higher productivity and revenue gains. However, not all farmers have chosen to make use of the possibility to extend seasons. Some farmers simply did not recognize this as an opportunity and took out the plants at the usual time despite the fact that they were still producing. Others noted that continuing to harvest and then transport crops from the multi-span only would not be economical as fuel for transport is expensive. These practices, though understandable, likely mean that the real potential for yield and revenue increases is still underestimated here.

As summarized in the diagram below, some farmers in Akkar chose to go for extended winter and summer seasons, while others decided to insert shorter spring and/or fall seasons in between. Unfortunately, some farmers suffered from a lack of resources and chose not to plant any crops throughout the summer season for lack of budget to acquire seeds and inputs. These practices are a reflection of the ongoing economic and financial crises and have unfortunately negatively affected results of the trial.

► Overview of seasonality and planted crops on farms in Akkar

	Winter 2020/2021	Spring 2021	Summer 2021	Fall 2021
Youssef Taoum	Cucumber		Cucumber	
Issam Hamad	Cucumber	Tomato	Solarization	Cucumber
Ahmad Olayen	Tomato			
Miled Dib	Tomato		Solarization	Cucumber short season
Khaled Abbas	Cucumber			
Souhaib Talawi	Cucumber		Cucumber / Solarization	

The following sections will outline results obtained on each individual farm. For the six farmers in Akkar, results for the different seasons as well as total results for the whole year are presented. The farmers in the Bekaa only plant tomatoes and cucumbers during the summer season and results presented thus refer to this season.

5.3. Results on farms in Akkar

Youssef

Youssef started the first season in November 2021 and transplanted cucumber seedlings of the variety *Noursun* on 11 November. The harvest period extended for 2.5 months until 30 March. Youssef decided to harvest the cucumbers of relatively small size to suit the demand of a specific off-taker. Youssef started a second season at the end of June and production lasted for four months in the multi-span during this summer season. This is considered as a long season for cucumber especially when planted in summer in the coastal area, considering that the crop faces stress due to the high temperature and large population of insects.

During the first season, Youssef was able to increase yields in the multi-span by 44.4% compared to the traditional greenhouse. Revenues in the multi-span were 48% higher than in the traditional structure. During the second season the difference between the two structures became even more apparent, and the yield in the multi-span greenhouse was around triple of that in the traditional greenhouse (235% increase).

This result was obtained as Youssef was able to extend the season in the multi-span, and obtain five more harvests from the multi-span when crops in the traditional greenhouse had already stopped producing (see Picture 13 below). Due to higher crop quality obtained in the multi-span, revenues in the modern structure were 255% higher than in the traditional one. When the results were corrected for the lost space between the two traditional greenhouses, the yield/m² increases amounted to 277%, and revenue/m² increases to 299%.

Looking at the full year, Youssef was able to obtain average yield increases of 113% and average revenue increases of 149.4%. When accounting for the land lost between the tunnels, revenue increases amount to 180.6%.

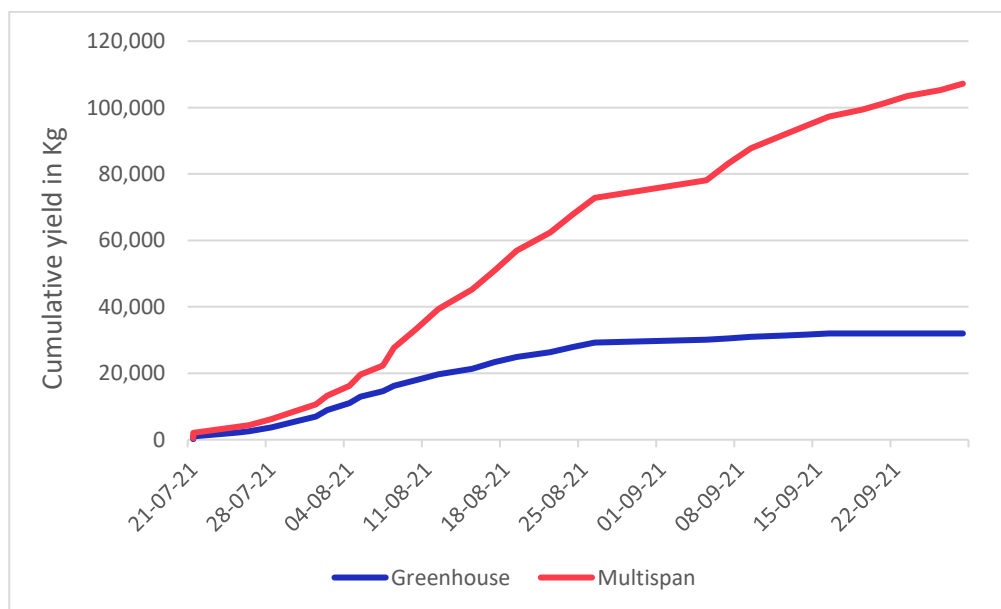
- Results of pilot trials on greenhouse productivity and working condition with 12 selected farmers in Akkar and the Bekaa

► Youssef's greenhouses

Pictures taken on 16 September 2021, traditional greenhouse left, multi-span greenhouse right



► Comparison of cumulative cucumber yield in traditional vs multi-span greenhouse Youssef, July - September 2021

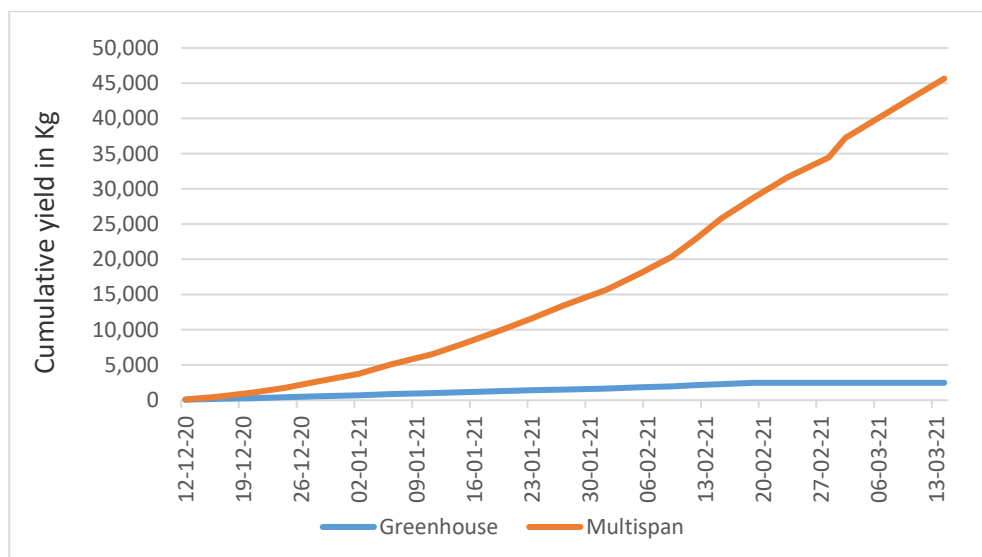


Issam

Issam started the first season early and transplanted cucumber seedling of the variety *Hiba* on 27 October 2020. The harvest lasted from 12 December until 14 March 2021, for roughly 3 months. In the modern multi-span greenhouse, the total yield reached 6,495 Kg, which represents an increase of 162% compared to the traditional structure. Revenues in the multi-span were 223% higher than in the traditional greenhouse. When correction is made for the land lost between two tunnels, the yield and revenue increases amount to 195% and 263% respectively.

This high difference in yield and revenues can be attributed to a virus disease (CYSDV) transmitted by whiteflies which devastated the two traditional tunnels but not the multi-span greenhouse, because the latter was well protected by insect-proof nets on the sides and a safety access door. These increases cannot be considered normal, but reflect the protection that the double-span may provide against vector borne diseases.

► Comparison of cumulative cucumber yield in traditional vs multi-span greenhouse Issam, December 2020 – March 2021



Due to the virus, Issam took out the cucumber plants early and then started a short 3-month season of tomatoes, with cuttings of a Syrian variety of tomatoes taken from neighbouring greenhouses planted. Yields and revenues in the multi-span for this spring season were 23 % higher than in the traditional greenhouse. Yield and revenue increases amounted to 38.5% after the correction for the lost space between the two traditional greenhouses. Revenues for the full year were thus 59% in the multi-span than in the traditional structures. When accounting for the land lost between the tunnels, Issam was able to obtain revenue increases of 78.9%.

► Tomato production in Issam's multi-span greenhouse



Ahmed

Ahmed transplanted his tomato seedlings of the variety *Sacha* on 14 October 2020 and harvested for only 2 months from 26 February to 26 March 2021. This is considered a very short harvest period for tomato and it was triggered by a severe infection by the fungus *Botrytis* in both structures. Ahmed had chosen a very high crop density which negatively affected climate and light exposure of the plants. The plants thus became less hardy and more susceptible to infection. Due to these issues, it was very difficult to stop the progress of the disease and thus the yield and revenue differences were minimal between the two types of structures.

The yield in the multi-span averaged 8.74 Kg/m², which represents an increase of 5.6% compared to yield in the traditional structure. Revenue increases amounted to 9.7%. When correction is made for the space between tunnels the difference in yield increases to 19% and the difference in revenues to 23.4%. Unfortunately, Ahmed Olayen could not afford the seedlings and inputs required to continue for a second season, and thus left both the traditional and the multi-span greenhouses unplanted for the remainder of the year.

Miled

Miled started his first season relatively late on 15 December 2020, when he planted the tomato variety *Switch*. The harvest period lasted for 2.5 months, from 9 March to 24 June 2021. The average yield in the multi-span was 23.7 Kg/m², representing an increase of 18% compared to yield in the traditional

tunnel. Revenues in the multi-span were 19.4% higher than in the traditional structure. When correction is made for the space between tunnels the yield increase becomes 32.7% and the increase in revenues becomes 34.3%.

It should be clearly noted though that differences in revenue between both structures were most likely significantly underestimated. Miled reported tomatoes of higher quality and size in the modern structure. When selling his tomatoes at the wholesale market, he therefore decided to put the tomatoes from the multi-span on top of the tomato boxes harvested from his traditional structures in order to get a better price for all his tomatoes. Experts confirmed that prices obtained for the bigger and nicer tomatoes from the modern structure should have been higher than prices obtained for tomatoes from the traditional structure. Hence, the difference in revenues between both structures would actually be much higher.

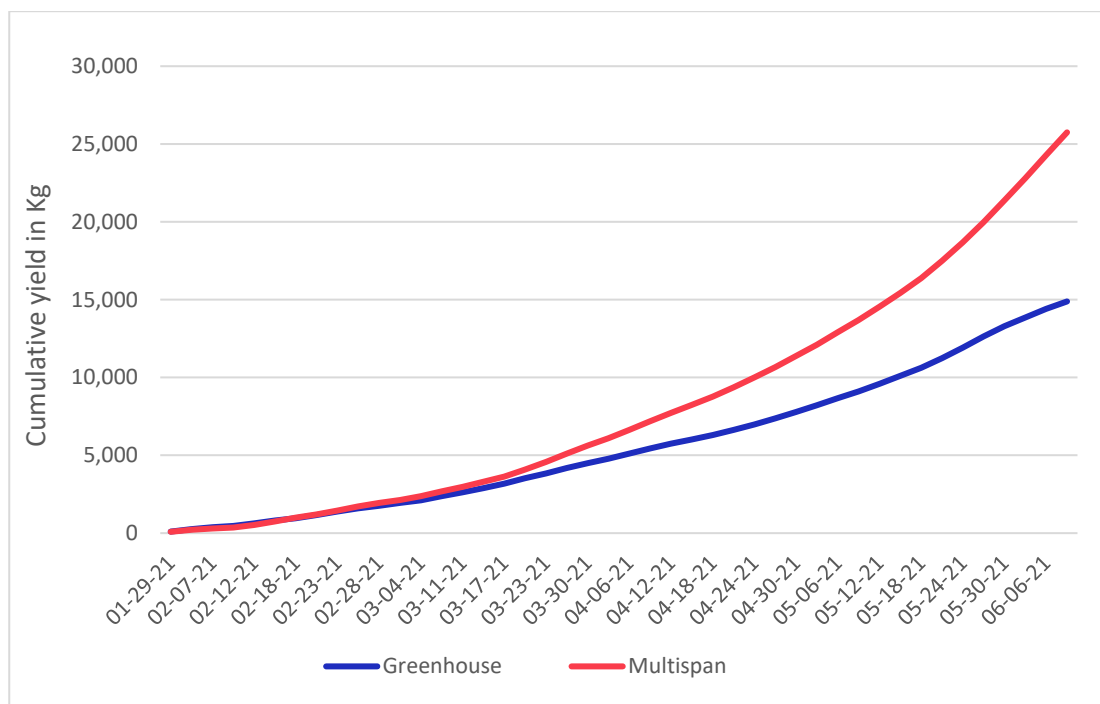
► Tomatoes of high quality and size in Miled's multi-span greenhouse



Khaled

Khaled transplanted seedlings of the cucumber variety *Mira* on 9 November 2020 and had the longest harvest period of about 4.4 months, from 29 January until 9 June 2021. Khaled reported that he would normally have taken out the crops earlier, but decided to extend the season when he noticed that plants in the multi-span were still producing well. Khaled recorded the highest yield among the four farmers who planted cucumbers, with yield reaching 38.8 Kg/m² in the multi-span greenhouse. The yield in the multi-span was about 75.1% higher than that of the traditional tunnels, and the revenues were higher by 79%. When correction is made for the land lost between two tunnels, the difference in yield amounts to 97% and differences in revenues to 102%.

Figure: Comparison of cumulative cucumber yield in traditional vs multi-span greenhouse Khaled, January – June 2021



Souhaib

Souhaib transplanted seedlings of the cucumber variety *Mira* on 11 November 2020 for his first season. He harvested for a period of about 2.6 months, between 10 January and 29 March 2021. The average yield/m² in the multi-span was 7.65 Kg, almost 17% higher than in the traditional tunnel structures. Differences in prices obtained for the crops produced in both structures were minimal and hence, the difference in revenue also amounted to almost 17%. When correction is made for the land lost between two tunnels, the yield and revenues increase amount to 31%. A fungus disease infected the plants in both the tunnels and the multi-span. As differences between both structures are usually more expressed towards the end of the season, the disease may well have reduced the differences in yield and revenues.

For the second season, Souhaib, also planted cucumbers. Cucumber seedlings were planted in early June, and Souhaib was able to harvest six times before deciding to remove all crops. Unfortunately, plants in all of Souhaib's traditional structures had stopped producing for an unknown reason. Even though plants in the multi-span greenhouse continued to produce, Souhaib decided to stop the harvest and remove all plants, including the ones in the modern greenhouse, since it was not manageable for him to harvest and transport the production of just one modern greenhouse alone. It should be noted that this decision was related to the severe fuel crisis that Lebanon experienced in summer 2021 that made transporting goods extremely cumbersome and expensive.

For this short season, the yield/per m² obtained in the multi-span amounted to 2.33 Kg compared to only 0.92 Kg for the traditional structure, a difference of 153.3%. It should be noted though that Souhaib's decision to remove the plants in the modern structures even though they were still producing, though understandable, was unfortunate as it made it impossible for the project team to record the real difference in yields and revenues between structures, that would likely have been much

► Results of pilot trials on greenhouse productivity and working condition with 12 selected farmers in Akkar and the Bekaa

higher. Looking at differences throughout the whole year, Souhaib was able to obtain revenue increases of 36.6%. When factoring in the space lost between tunnels, revenue increases amount to 53.5%

► Results of pilot trials on greenhouse productivity and working condition with 12 selected farmers in Akkar and the Bekaa

Table: overview of yield and revenue increases on the six farms in Akkar

(yields measured in kg/m²; sales measured in LBP/m²)

Yussuf - Cucumber													
Winter season 2020/21			Spring season 2021			Summer season 2021			Full year			Revenue increase:	Revenue increase/land used:
Yield - Trad	Yield - Modern	% difference				Yield - Trad	Yield - Modern	% difference	Yield - Trad	Yield - Modern	% difference	Yussuf: 149.4%	Yussuf: 180.6%
5.71	8.25	44.4				3.21	10.8	235.2	8.92	19.01	113.0		
Sales - Trad	Sales - Modern	% difference				Sales - Trad	Sales - Modern	% difference	Sales - Trad	Sales - Modern	% difference		
20,515	30,376	48.1				19,702	69,917	254.9	40,217	100,293	149.4		
Souhaib - Cucumber													
Winter season 2020/21			Spring season 2021			Summer season 2021			Full year			Revenue increase:	Revenue increase/land used:
Yield - Trad	Yield - Modern	% difference				Yield - Trad	Yield - Modern	% difference	Yield - Trad	Yield - Modern	% difference	Souhaib: 36.6%	Souhaib: 53.5%
6.54	7.64	16.9				0.92	2.33	153.3	7.46	9.97	33.7		
Sales - Trad	Sales - Modern	% difference				Sales - Trad	Sales - Modern	% difference	Sales - Trad	Sales - Modern	% difference		
19,349	22,543	16.5				3,256	8,333	155.9	22,605	30,876	36.6		
Issam - Cucumber/Tomatoes/Cucumber													
Winter season 2020/21			Spring season 2021			Fall season 2021			Full year			Revenue increase:	Revenue increase/land used:
Yield - Trad	Yield - Modern	% difference	Yield - Trad	Yield - Modern	% difference	Yield - Trad	Yield - Modern	% difference	Yield - Trad	Yield - Modern	% difference	Issam: 57.8%	Issam: 78.9%
3.74	9.78	161.9	9.79	12.05	23.1	4.73	7.29	54.2	18.25	29.12	59.6		
Sales - Trad	Sales - Modern	% difference	Sales - Trad	Sales - Modern	% difference	Sales - Trad	Sales - Modern	% difference	Sales - Trad	Sales - Modern	% difference		
11,306	36,489	222.7	51,657	63,630	23.2	23,054	35,575	54.3	86,017	135,694	57.8		
Khaled - Cucumber													
Winter season 2020/21			Spring season 2021			Summer season 2021			Full year			Revenue increase:	Revenue increase/land used:
Yield - Trad	Yield - Modern	% difference							Yield - Trad	Yield - Modern	% difference	Khaled: 79.2%	Khaled: 102
22.15	38.78	75.1							22.15	38.78	75.1		
Sales - Trad	Sales - Modern	% difference							Sales - Trad	Sales - Modern	% difference		
75,657	135,580	79.2							75,657	135,580	79.2		
Ahmed O. - Tomatos													
Winter season 2020/21			Spring season 2021			Summer season 2021			Full year			Revenue increase:	Revenue increase/land used:
Yield - Trad	Yield - Modern	% difference							Yield - Trad	Yield - Modern	% difference	Ahmed: 9.7%	Ahmed: 23.4%
8.27	8.74	5.6							8.27	8.74	5.6		
Sales - Trad	Sales - Modern	% difference							Sales - Trad	Sales - Modern	% difference		
2,575	2,824	9.7							2,575	2,824	9.7		
Miled - Tomatos													
Winter season 2020/21			Spring season 2021			Fall season 2021			Full year			Revenue increase:	Revenue increase/land used:
Yield - Trad	Yield - Modern	% difference				Yield - Trad	Yield - Modern	% difference	Yield - Trad	Yield - Modern	% difference	Miled: 30.5%	Miled: 34.3%
20.08	23.70	18.0				0.7	1.3	100.0	20.74	25.01	20.6		
Sales - Trad	Sales - Modern	% difference				Sales - Trad	Sales - Modern	% difference	Sales - Trad	Sales - Modern	% difference		
41,939	50,066	19.4				6,619	13,306	101.0	48,558	63,372	30.5		
Average:												60.5%	78.8%

5.4. Results of farms in the Bekaa

Hanna

On the farm of Hanna, tomato seedlings of the variety *Red Flora F1* were transplanted on 20 May 2021 and harvest extended for 140 days, from 5 August to 24 December 2021. Hanna Daibis reported some leaf burns on the plants during July and August due to the high heat, though the problem was more expressed in the traditional tunnels than in the multi-span structures. Overall, Hanna Daibis observed fewer pest problems in the modern structures. In the multi-span greenhouses, yield reached an average of 11.5 Kg/m², and thus 28% more than the average yield in the tunnels. Revenues were 28.5% higher in the multi-span greenhouse. When correction is made for the land lost between two tunnels, revenues increased by 38.5 %.

- Difference in plant vigour between plants in the multi-span (left) and the traditional structure (right) in Hanna greenhouses on 8 November 2021



Omar

Omar transplanted cucumber seedlings of the variety *Datis F1* on 6 June 2021. Despite instructions by the project to apply the same production practices in both greenhouses, Omar Bou Khater decided to plant at a higher density in the multi-span as he estimated that the improved climate in the modern structures would allow higher density without jeopardizing the health and vigour of the plants. He

► Results of pilot trials on greenhouse productivity and working condition with 12 selected farmers in Akkar and the Bekaa

planted 3.45 plants/m² in the multi-span compared to 2.88 plants/m² in the tunnels. The harvest period extended from 30 June to 20 October 2021.

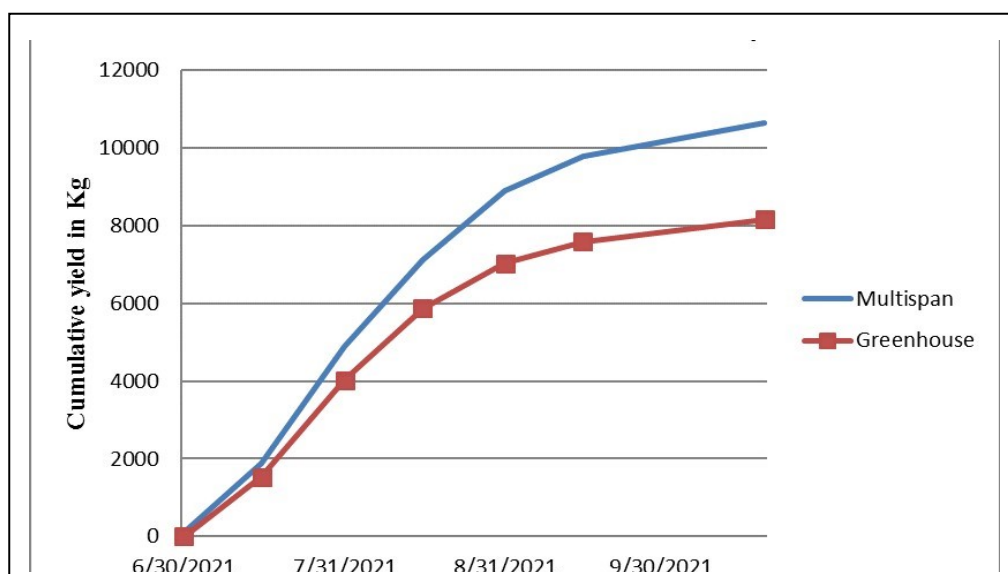
Despite the higher density which would usually result in increased occurrence of diseases, the plants in the multi-span performed much better than those in the tunnels, with better vegetative growth, better fruit quality and significantly higher yield (see Figure below). The incidence and severity of pests including thrips, mites, whiteflies and powdery mildews were significantly lower in the modern structures as compared to the tunnels. In July and August, when the temperature increased, some flower and fruit abortion were observed and which was caused by poor aeration.

Consequently, in the multi-span, the total yield reached an average of 16 Kg/m², 30.6% higher than the average yield in the tunnels. Omar was also able to obtain higher prices for the cucumbers produced in the multi-span greenhouse, resulting in revenues that were 46.6% higher than in the traditional greenhouse. When correction is made for the land lost between two tunnels, revenue increases amount to 64.9%.

► Difference in plant vigour between plants in the multi-span (left) and the traditional structure (right) in Omar greenhouses on 2 October 2021



► **Figure: Comparison of cumulative cucumber yield in traditional vs multi-span greenhouse Omar, June - September 2021**



Wadi

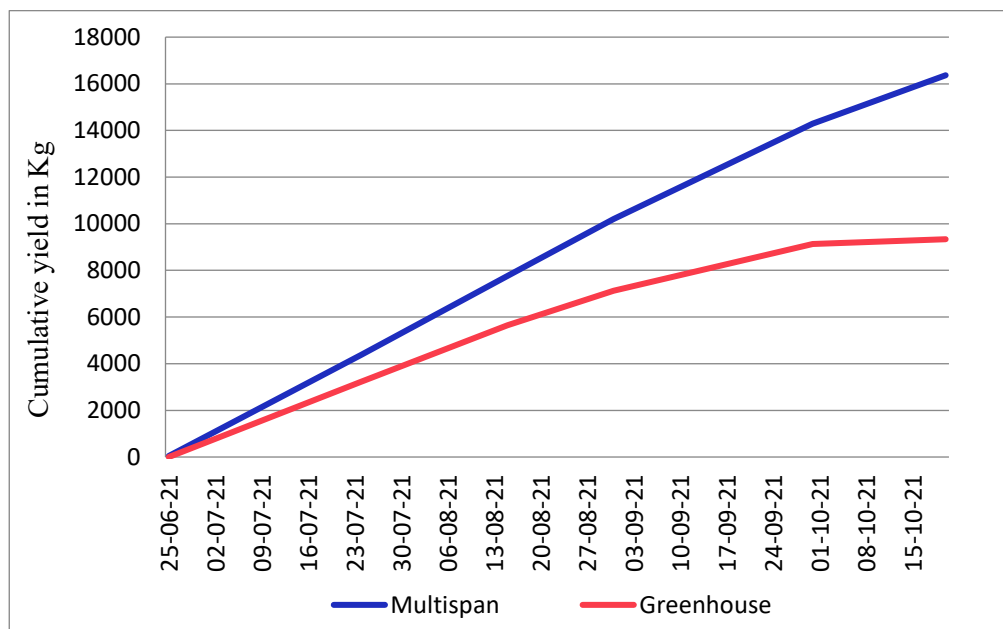
Wadi transplanted cucumber seedling of the variety *Mania F1* on 26 June, somewhat late compared to the other farmers. He harvested between 29 July to 4 October 2021, for only 68 days. The yield in multi-span reached an average of 7.95 Kg/m², 15.7% more than the average yield in the traditional structures. As productivity differences between the structures are most expressed towards the end of the season, the relatively low difference in yield in Wadi Khazaka's greenhouses may be attributed to the relatively short harvest season due to late planting. Revenues in the modern structure were 18.5% higher than in the traditional ones, due to better quality of fruits. When correction is made for the land lost between two tunnels, revenue increases amount to 33.3%.

Ahmed

Ahmed transplanted cucumber seedlings of the variety *Rania F1* on 26 May 2021. He had the longest harvest period of all farmers, lasting about 4.5 months, from 25 June to 10 Nov 2021. Ahmed applied additional measures to keep temperatures cool during the summer, and sprayed lime on roofs of all greenhouses in June. He also used a sprinkler system that seemingly reduced temperature about 5 °C. Harvest in the multi-span started a few days earlier and lasted for about 20 days longer in the modern greenhouse than in the traditional greenhouse.

Ahmed recorded the highest yield among the three farmers. In the multi-span, yield reached 24.6 Kg/m², an exceptionally high yield for Lebanon in similar conditions. The yield was 74.2% higher than that of the traditional tunnels, with revenues being 80% higher. When correction is made for the land lost between two tunnels, revenues increase amount to 102.5%.

► **Figure: Comparison of cumulative cucumber yield in traditional vs multi-span greenhouse**
Ahmed, June - October 2021



- Results of pilot trials on greenhouse productivity and working condition with 12 selected farmers in Akkar and the Bekaa

- **Picture: Differences in the vigour of plants in the multi-span (left) and the traditional structure (right) of Ahmed are already visible early in the season, on 26 July 2021**



Kassem

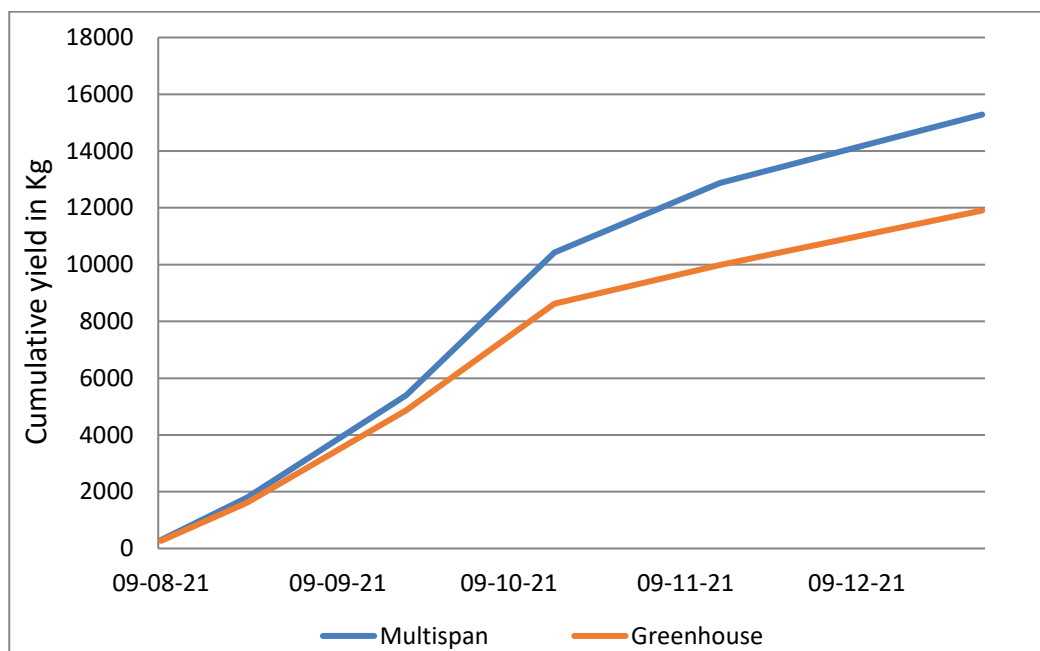
Kassem transplanted tomato seedlings of the variety *Evita* on 17 June 2021. He planted a higher density in the chapel: 10 rows in the Chapel as compared to 8 rows in the tunnels. The harvest period extended for 143 days from 9 August to 31 December 2021. The plants in the double span performed better than those in the tunnels and were also taller. Incidences and severity of pests like mites, leaf miners, tuta absoluta, botrytis and powdery mildew were significantly lower in the multi-span compared to the tunnels, despite the fact that Kassem Younes sprayed pesticides every 14 days in the tunnels, and only every 21 days in the chapel.

In July-August, he complained about temperature increases and he believes that tomato yield could be even higher in the multi-span if aeration were improved. In the multi-span, the yield reached an average of 23 Kg/m², an exceptionally high yield for Lebanon in similar conditions. The yield was about 22.4 % higher than that of the tunnels, with revenues increasing by 23.2%. When correction is made for the land lost between two tunnels, revenues increased by 38.6%.

- **Picture: Differences in vigour of plants in the multi-span (left) and the traditional structure (right) of Kassem already visible in September (below) and more expressed in late October (next page)**



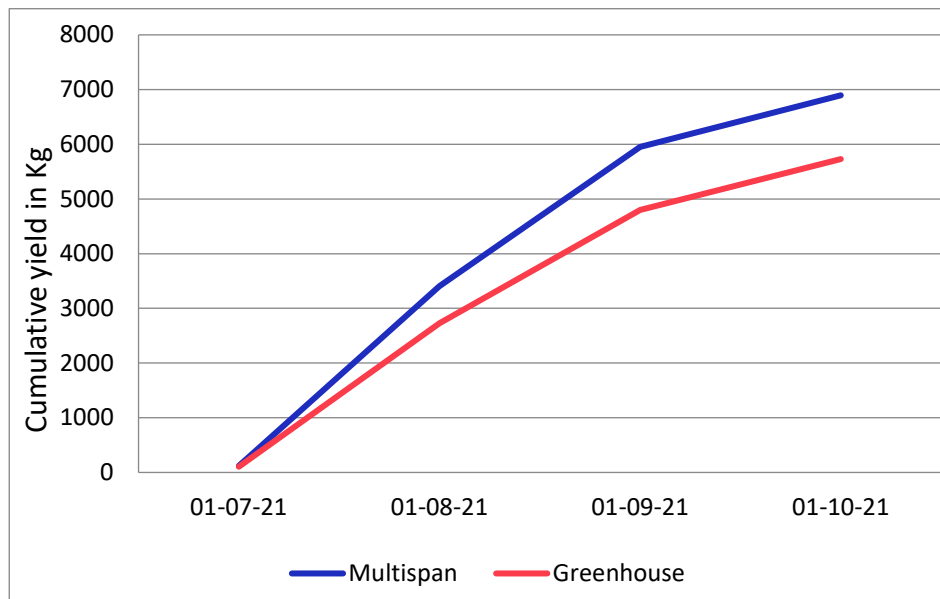
► **Figure: Comparison of cumulative cucumber yield in traditional vs multi-span greenhouse Kassem, August – December 2021**



Yasser

Yasser transplanted tomato seedlings of the variety *Bayda F1* on 12 May 2021, and his harvesting period extended for only 109 days starting from 12 July to 29 October 2021. Unfortunately, it became apparent during the season that the farm of Yasser is infected with a soilborne disease. Because the disease is caused by infected soil, plants in both types of structures experienced soilborne disease problems that shortened the harvest period and reduced yield. In the multi-span, the total yield reached an average of 8.6 Kg/m², 18.9 % higher than the average yield in the tunnels, with revenues being 20.8% higher. When correction is made for the land lost between two tunnels, revenue increases amount to 36%.

► **Figure : Comparison of cumulative cucumber yield in traditional vs multi-span greenhouse**
Yasser, July – October 2021



► Results of pilot trials on greenhouse productivity and working condition with 12 selected farmers in Akkar and the Bekaa

Table: overview of yield and revenue increases on the six farms in the Bekaa

(yields measured in kg/m²; sales measures in LBP/m²)

Ahmed H.- Cucumber										
Season 1			Season 2			Full year			Total increase in revenue:	Total increase in revenue adjusted for land used:
			Yield - Trad	Yield - Modern	% difference				Ahmed: 80%	Ahmed: 102.5%
			14.06	24.5	74.2					
			Sales - Trad	Sales - Modern	% difference					
			77,087	138,768	80.0					
Omar - Cucumber										
Season 1			Season 2			Full year			Total increase in revenue:	Total increase in revenue adjusted for land used:
			Yield - Trad	Yield - Modern	% difference				Omar: 46.6%	Omar: 64.9%
			12.29	16.05	30.6					
			Sales - Trad	Sales - Modern	% difference					
			62,852	92,139	46.6					
Kassem - Tomato										
Season 1			Season 2			Full year			Total increase in revenue:	Total increase in revenue adjusted for land used:
			Yield - Trad	Yield - Modern	% difference				Kassem: 23.2%	Kassem: 38.6%
			18.80	23.02	22.4					
			Sales - Trad	Sales - Modern	% difference					
			163,592	201,495	23.2					
Wadi - Cucumber										
Season 1			Season 2			Full year			Total increase in revenue:	Total increase in revenue adjusted for land used:
			Yield - Trad	Yield - Modern	% difference				Waddi: 18.5%	Waddi: 33.3%
			6.90	7.98	15.7					
			Sales - Trad	Sales - Modern	% difference					
			41,727	49,453	18.5					
Hanna - Tomato										
Season 1			Season 2			Full year			Total increase in revenue:	Total increase in revenue adjusted for land used:
			Yield - Trad	Yield - Modern	% difference				Georges: 28.5%	Georges: 38.5%
			8.98	11.50	28.0					
			Sales - Trad	Sales - Modern	% difference					
			68,904	88,541	28.5					
Yasser - Tomato										
Season 1			Season 2			Full year			Total increase in revenue:	Total increase in revenue adjusted for land used:
			Yield - Trad	Yield - Modern	% difference				Yasser: 20.8%	Yasser: 36%
			8.63	10.26	18.9					
			Sales - Trad	Sales - Modern	% difference					
			46,574	56,283	20.8					
Average:									36.3%	52.3%

6. Lessons regarding productivity, yield and revenues

6.1. Differences in crops

As mentioned before, differences in pure productivity have been found to be higher for cucumbers than for tomatoes as cucumbers are more sensitive to climate conditions. Yield increases for tomato averaged 20.4%, while yield increases for cucumbers averaged 96.6%. This is important information that should be disseminated to farmers together with information on the exact benefits of multi-span greenhouses in terms of productivity, quality and production costs.

6.2. Impact on production costs

Farmers that participated in this trial were explicitly asked to apply the same production practices, i.e. the same amount and type of pesticides and fertilizers in both the traditional and the modern greenhouse. Hence, any potential to decrease production costs in the multi-span could not be measured. It is however highly likely that production costs can be reduced significantly by upgrading to multi-span greenhouses. Since crops are naturally better protected against pests and diseases, fewer pesticide sprays are needed to fight the onset of these.

That said, it is unfortunately a common practice of farmers to spray a mix of pesticides at regular intervals in order to prevent diseases and pests from occurring, rather than spraying specific pesticides and treatments when detecting pests. Hence, whether or not any potential to reduce production costs in multi-span greenhouses can be realized will largely depend on the proficiency level of farmers and their ability to adapt production practices in multi-spans.

6.3. Revenue gains through price differences for quality produce

Next to substantial differences in pure productivity, as measures by yield per m², trials have confirmed that the quality of crops is much improved in multi-span greenhouses. However, to what extent this quality difference translates into higher prices and revenues for farmers depends on the market dynamics and the specific relationships farmers have with wholesalers or other off-takers. Unfortunately, many farmers are price-takers and do not have substantial bargaining power vis-à-vis wholesalers. Particularly in Akkar, farmers often receive up-front financing from wholesalers for agricultural inputs.² This means that at the time of harvest, farmers are indebted to wholesalers and are in no position to negotiate prices.

Hence, there may well be potential to further increase revenues for high-quality crops produced in multi-spans if farmers' bargaining power vis-à-vis wholesalers can be increased. Experts confirmed that specific restaurants, catering services and high-end hotels would be able to pay more for produce of higher quality and size but realizing this potential for further revenue increases will require work to better connect farmers to specific off-takers and buyers that are ready to pay more for higher quality.

Trial results likely underestimated the revenue gains that can be obtained by upgrading to multi-span greenhouses due to the common practices of farmers to mix crops of higher quality and size with inferior crops.

² This was confirmed through a recent survey conducted by ILO: [the state of covered horticulture in Lebanon](#)

While farmers were explicitly told to sell the crops from multi-span greenhouses separately in order to keep track of revenues in the different structures, some farmers did not stick to these instructions and put the higher quality crops of multi-spans on top of boxes with inferior produce, so as to obtain higher prices for all crops. This indicates that, had they clearly separated the crops from the different structures, the revenue gains would likely have been much higher.

6.4. Aeration

Several farmers in the Bekaa complained about poor aeration in the double-spans. When experts inspected the insect-proof nets, they found that these seemingly did not fit the required quality for the region, as pore sizes were very small and reduced aeration in the multi-span. According to experts, there is a trade-off between good aeration and protection against pests when choosing the correct pore size for nets: increasing pore sizes means better aeration but lower protection against pests, while decreasing pore sizes means reduced aeration but better protection against pests.

Three farmers in the Bekaa expressed their believe that improved aeration through nets with increased pore sizes would have the potential to increase yields even further. Further research and trials would be needed to determine the optimal pore sizes in any given region and micro-climate in Lebanon.

7. Results of surveys on working conditions

Next to benefits in terms of increased productivity and revenues, trials have confirmed that multi-span greenhouses also improve the working conditions for greenhouse workers. Interviews with 19 workers on the 12 participating farms have confirmed that the overwhelming majority of workers on these farms would prefer to work in multi-span greenhouse rather than in traditional greenhouses.

According to the 19 workers interviewed, the main working condition deficits associated with work in traditional greenhouses are heat and exposure to chemicals, and to some extent the fact that work is perceived as strenuous. Responses are summarized in the table below.

► **Table: Responses of the 19 surveyed workers regarding main working condition deficits:**

Main work condition deficits:	Chemicals	Heat	Accidents	Strenuous work	Long working hours
No, not at all	3	0	11	1	8
Yes, it's a problem but not a major one	12	7	5	11	8
Yes, it's a huge problem	4	12	3	7	3

When asked whether they would prefer to work exclusively in modern multi-span greenhouses, 14 out of the 19 workers said yes, while 5 workers said they are indifferent. When asked about the specific advantages of multi-span greenhouses, workers cited lower heat in multi-spans (13 out 19 workers), more space to move (12 out of 19), less strenuous work (7 out of 19 workers), better aeration (5 out of 19) and fewer insects (4 out of 19) as advantages.

Workers' surveys also once again confirmed the benefits of multi-spans in terms of productivity and production, with the vast majority of workers seeing huge differences in yields and quality of crops in multi-span as well as lower occurrence of pests, as summarized in the table below.

► **Table: Responses of the 19 surveyed workers regarding differences in production and yield**

Difference in production:	Yield per greenhouse	Quality of crops	Pest occurrence
No, not at all	0	2	2
Yes, a small difference	6	5	4
Yes, a huge difference	13	12	13

8. Lessons and conclusions

8.1. Lessons from the trial

The trials conducted with selected farmers in Akkar and the Bekaa have confirmed that upgrading greenhouses from traditional structures to multi-span greenhouse can have substantive benefits for farmers. Data collected on the 12 farms showed substantial increases in pure productivity in the multi-spans, with yields of tomato production averaging 20.4% (18% in Akkar and 23% in the Bekaa), and yield increases for cucumbers averaging 66.2% (80.5% in Akkar and 45.9% in the Bekaa).

Crops in the multi-span were also found to be of higher quality and size than those in the traditional structures which often translates to higher prices for crops produced in the multi-span. Data obtained from the 12 farms showed revenues from tomato production in the multi-span increased by an average of 24.7% (26.3% in Akkar and 24.1% in the Bekaa), while revenue increases from cucumber production averaged 74.7% (96% in Akkar and 54.3% in the Bekaa).

An additional advantage of multi-span greenhouses consists of the possibility to use all land for production. Traditional tunnels require a space of 2-3 meters between two single tunnels that cannot be used for effective production. Multi-span greenhouses on the other hand provide the possibility to use all the land for production without leaving space between tunnels. When accounting for the additional land used between the tunnels, revenue gains obtained in the multi-span for tomatoes average 39.2% (42.1% in Akkar and 38.1% in the Bekaa), while adjusted revenue increases from cucumbers averaged 96.6% (120.9% in Akkar and 73.6% in the Bekaa).

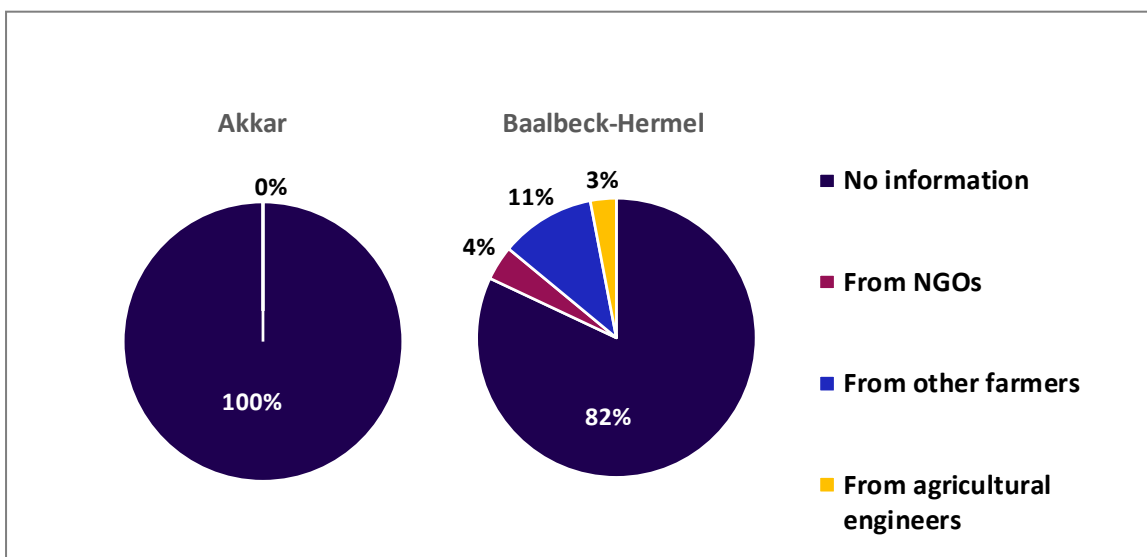
Next to these benefits in terms of productivity and revenues, trials confirmed that potential exists to reduce production costs in multi-span. As plants are better protected from pests and diseases, fewer pesticide sprays are needed to fight the onset of pests, though these benefits could not be quantified through the trials.

Surveys with workers also confirmed that working conditions in multi-span greenhouses are much improved as these are better ventilated, and temperature and humidity is usually lower in multi-spans. Workers also noted fewer insects in the modern structures and appreciated that there is more space to move. Additional to working condition improvements, multi-span greenhouse hold environmental benefits as they are more water efficient and require fewer sprays of harmful pesticides.

Yet, recently conducted surveys have confirmed that the vast majority of farmers are not aware of these benefits.³ Surveys conducted with 200 greenhouse farmers in Akkar and the Bekaa confirmed that these receive little specific, evidenced information on the benefits of multi-span greenhouses, and consequently have very little knowledge of these benefits. Only 18 farmers (9%), all in the Bekaa, have received information on the benefits of modern greenhouses, either from other farmers, NGOs or agricultural engineers. Even if farmers received information, it usually pertained to basic information on specifications of multi-span greenhouses, not on benefits in terms of productivity, yield, quality of produce, pest resistance or extended agricultural seasons.

³ Full survey report available online: [ILO, 2021 - The state of covered horticulture in Lebanon](#)

► Figure: Percentage of farmers that received information on benefits of multi-span greenhouses by source



Source: ILO, 2021: The state of covered horticulture in Lebanon

Consequently, when asked about the benefits of modern greenhouses, 33% of interviewed farmers in the Bekaa and 13% in Akkar stated that they don't know about these. Other farmers were vaguely aware of some of the benefits, and stated that there is better ventilation and thus lower humidity in the multi-span greenhouses (56% in Akkar, 18% in the Bekaa). Only 3% of surveyed farmers in Akkar and 5% in the Bekaa were aware that plants in modern greenhouses are less prone to diseases and thus require fewer pesticide sprayings. No interviewed farmer mentioned productivity benefits, extended seasons or improved quality of the produce.

The lack of knowledge of the exact benefits of multi-span greenhouses is clearly not the only factor hindering farmers from investing in modern structures. Particularly in times of crises, few farmers are able to afford this investment that requires substantive up-front cash payment in US dollars. Nevertheless, unclarity about the benefits and thus the exact return to this investment constitutes an additional hurdle and more needs to be done to inform farmers about the exact benefits in terms of productivity, yield, production costs and revenues that multi-span greenhouses can bring to them.

8.2. Next steps of ILO under PROSPECTS

The completed pilot trials on productivity and working conditions with 12 farmers have confirmed that upgrading greenhouses to multi-span greenhouses has immense benefits for both farmers and workers. While farm owners benefit from increased productivity and ultimately higher revenues and incomes, surveys confirmed that multi-span greenhouses also substantially improve working conditions for the mostly Syrian greenhouse workers. In times where many farmers have seen their profits plummet due to the crises and have thus started to abandon their farms and let go of their workers, helping farmers upgrade to high-productivity multi-span greenhouse can be an important measure to safeguard jobs and livelihoods of both farm owners and their workers.

Moving forward, ILO PROSPECTS will thus be working to tackle the two main identified constraints that currently limit the uptake of high-productivity multi-span greenhouses by farmers: limited information about the specific benefits of multi-span greenhouses with regard to productivity and revenues, and lack of access to finance. The

programme will be working with a variety of local stakeholders to launch a series of information campaigns in an effort to better inform farmers about the specific benefits that modern multi-span greenhouses can bring to them. These actions will go hand-in-hand with measures to facilitate farmers' access to financial support in the form of both subsidy and micro-credit schemes, so as to enable them to invest in multi-span greenhouses.

Under the PROSPECTS Programme, ILO is implementing a comprehensive strategy to promote decent work in the agricultural sector for both Lebanese host communities and Syrian refugees, including through improved working conditions and better social protection for both groups. To this end, a variety of more detailed studies have been conducted or are underway to shed more light on social protection frameworks, working conditions and occupational safety and health (OSH) in Lebanon's agriculture sector. These studies and subsequent consultations with stakeholders at the local and national level will form the basis for actions in these areas under PROSPECTS. ILO PROSPECTS will also continue to support MSMEs in the agriculture and agri-food sector more directly, through trainings on business continuity and financial support to help these enterprises adapt their strategies and business models in the face of the crises.

