WORKING PAPER[1]

Israeli Agricultural Innovation: Assessing the Potential to Assist Smallholders

Alon Tal

Professor and the Chair of the Department of Public Policy, Tel Aviv University

April 2019

[1] This is part of a series of research and policy publications on agricultural innovation systems in India, China and Israel. It is part of the Syngenta Foundation's Policy initiative.

Table of content

Part I. Israel's Agricultural Reality in Relation to Africa, India and China

Introduction

Israel's agricultural experience is unique. Despite the pervasive shortage of water, historic soil erosion and dryland conditions, a 2017 OECD report recognizes Israel's annual growth rate in total factor productivity for agriculture as being far above the world average.[1] Israel's innovations in agricultural technologies and general farming acumen have already begun to show their potential to contribute to progress in improving conditions for smallholders in Africa and Asia. This report focuses on new technologies and projects that show promise for improving yields, water management and overall sustainability amongst smallholder farmers, with an eye to potential in China, India and especially in Africa.

It is important at the outset to emphasize agrotech's limitations: It is not merely a question of technology transfer. Institutional arrangements and innovations remain critical for transforming the agricultural reality of economically depressed areas. Israel's exceptional achievements in agriculture are also a function of cultural factors which cannot be exported or easily transmitted in training courses. It is not a coincidence that the "kibbutz", historically, perhaps the single greatest source of Israel's agricultural innovation, is an idiosyncratic, intentional community. It emerged as an expression of the country's highly idealistic, Socialist founders' values and has not really been duplicated in other milieus. More recently, many of the agrotech initiatives to come out of Israel can be linked to applying technologies developed for the military to agricultural challenges.

It is also important to emphasize that the ostensible success of Israel's agricultural sector is not just a story of technological innovation, but also of policies and institutional frameworks which might be duplicated elsewhere. After describing the context of Israel's agricultural ties with India, China and Africa, the report offers a brief description of Israel's historic agricultural policies, orientation, institutions and programs. The report goes on to depict the "ecosystem" that has produced such a steady of stream of innovations in farming technology and practices. It also presents the role of incentives in increasing innovation among Israeli farmers and whether there are any insights for application in African that can be gleaned from Israeli public policies

The central focus of this study considers how Israeli research and new agrotech products might be utilized to improve the lot of smallholders in Africa, with implications for Chinese and Indian smallholders as well. The discussion begins with an exploration of some general consensus views among Israelis involved in agricultural work in Africa and Asia about the orientation required for meaningful results. Then the stories of several Israeli technological and agronomic advances are presented along with an assessment of their potential to strengthen agriculture in Africa and the developing world.

Africa and Israel

There are an estimated 51 million farms in Africa. Like 85% of the world's farmers, Most of

them are smallholders who work 20 or less hectares of land.[2] Yields in these farms tend to be extremely low, perpetuating the cycle of poverty and food insecurity in many regions throughout the world[3]. Indeed, one in nine people living on the planet continue to be defined by the United Nations Food and Agriculture Organization (FAO) as "hungry".[4] Research published in *Lancet* estimates that "undernutrition' causes over three million deaths among children annually or 45% of all child deaths.[5]

Most of the people who face such acute food shortages live in African communities that rely on small, low-input farms. With exceptional annual demographic growth still at roughly 3%, the continent is set to expand to 4 billion people by the end of the century, which assuming business as usual scenarios, will make preset shortages far worse.[6] Significant progress has been made in improving food security, in other areas of the world, however, suggesting that trend need not be destiny. Interventions and appropriate technologies can transform agricultural production and have already changed the lives of hundreds of millions of the world's poorest people. Notwithstanding isolated improvements among smallholders, unfortunately, average African yields remain stagnant. This report seeks to evaluate the potential of recent Israeli agricultural innovations to contribute to such a transformation in Africa as well as poor farming communities in India and China that have been left behind.

Israel's contribution to modern agriculture is extraordinary: among the many innovations which began in this small country are myriad new crop varieties such as *cherry tomatoes*, *galia melons* or *orangetti spaghetti squash*. New ideas -- from areas as diverse as efficient dairy farming, post-harvest treatments for shelf-life extensions to integrated pest management and use of drones for crop monitoring – that were initiated in Israel, inform and upgrade agricultural operations around the world. The country's contribution to sustainable irrigation practices, is unrivaled. This creativity and entrepreneurial capacity are well-recognized and reflected in global investments, with Israeli agrichtech attracting some 7% of the global funding for new technologies. But can Israel's innovative, technological prowess in agriculture be utilized to improve conditions of smallholders?

Providing appropriate technology to the continent's smallholders is critical. But the challenge cannot be understated. Over six hundred million Africans live without the benefit of electricity, cellular phone coverage, access to internet or clean water.[7] Expanding essential infrastructures, in particular access to inexpensive, renewable electricity and mini-grids must be central to any meaningful strategy for agricultural development. According to World Bank estimates, continuous energy supply alone could boost sub-Saharan economy by more than two percent a year. Power constitutes a critical obstacle to progress in agriculture: The Cambridge and Oxford University *Smart Villages* initiative concludes that once reliable and affordable electricity is available, even farmers with small holdings can begin to utilize a range of technologies: irrigation pumps or smart phones to receive weather forecasts.[8]

As the world becomes more and more urbanized, Africa remains a holdout: over half the population work as farmers and agriculture contributes to roughly a third of the sub-Saharan economy. Only about 5% of jobs are in manufacturing -- compared to 18% in other developing areas.[9]

At the same time, over the past few decades, total agricultural production in Africa has increased steadily: its value has almost tripled (+160%), and yields are comparable to those found in South America, (but below growth in Asia.) Unfortunately, there has been very little improvement in the key production factors (labor and land). That means that any expansion that the agricultural sector experienced has been largely achieved by cultivating more land and by mobilizing a larger labor force. This might be able to resolve recurrent food security emergencies created by rapid population growth. But, the minimal improvement in yields offers smallholders no meaningful pathway out of poverty. On average, cereal yields are less than half those obtained in Asia. And as more marginal lands are pressed into cultivation, soils are degraded and natural capital eroded.[10]

Most Israeli agrotech companies do not prioritize African sales, and general, most agrotech startups express little interest in developing products and applications that are appropriate for smallholders. While farm operations throughout the world increasingly benefit from new Israeli ideas that improve agricultural efficiency and yields, except for several agri-business enterprises and large corporate ventures Africa remains largely irrelevant.

Gil Haskel, is deputy director of Israel's Foreign Ministry and heads MASHAV, the country's foreign assistance agencies. As a former ambassador to Africa, he has considerable familiarity with the continent and knows which Israeli initiatives have been successful and which have not. Haskel argues that all countries in Africa have the resources to undertake successful agricultural projects with Israeli partners. It's simply a question of prioritizing resources: "If an African president chooses not to purchase a presidential air plane, the same funds could be used to launch transformational initiatives for the country's rural sector."[11]

Haskel points to numerous examples of successful public-private partnerships, with proven BOT (Build/Operate/Transfer) models, to magnify local resources, even without international assistance. But senior decision makers need to change their orientation. Sometimes, it is simply policy changes that are needed. For example, something as simple as charging for water could help attract partners for upgrading water infrastructure, without having to direct government resources to that end. In other cases, it is good governance. The continent's long and tragic history of corruption among senior politicians suggests that far too often, food security and a robust farming sector are simply not prioritized.

Political support and adoption of appropriate policies are critical for collaboration with Israeli agricultural partners to succeed. A recent case of the Galana Kulaluu River Project in Kenya is instructive: The Kenyan President personally endorsed transforming a million acres of land into maize production with the goal of increasing yields dramatically and reducing consumer prices. Israeli systems and companies were chosen to assist: Electric fences were built to keep animals away; pumping stations established; reservoirs built; lands were cleared and prepared.

Initial results were extraordinary.[12] The quality of corn was extremely high relative to local standards. (The project looked fundamentally different than other maize operations in the area because of the uniform height of the corn stalks.[13]) As laws of supply and demand began to take hold, the price of a kilogram of corn dropped from 120 shillings to 40. But then the influential local "Miller's Association", whose economic interests were not served

by the dropping of consumer prices, began to exert pressure so that today, the project is in danger of collapsing.[14]

While there is at least a symbolic element of idealism and altruism, Israel's Ministry of Agriculture's perspective on Africa is ultimately pragmatic. Director General of the Ministry, Shlomo Ben-Eliyahu oversees policy for the Ministry. He identifies three components that inform the present Israeli government's policies regarding Africa:

The first level is ideological. We have the perspective of the prophets: Israel needs to do well by the world. Food Security is a global challenge. We have a moral responsibility to address it. That's why the Ministry created CINADCO, to design and run courses and assist farmers in the developing world. On the political level: our agricultural work clearly has implications. Eliciting political support from African countries is important. That's why the Prime Minister traveled to Africa. That's why we host so many delegations. This matters a great deal to us. The third level is economic. But I think we need to be very realistic. A country as small as Israel cannot influence African economies. Our usual approach to research and the Israeli system for the most not part is not applicable to Africa[15].

Summary, Israel's African Opportunity

In recent years there has been a rising interest among African countries in identifying new Israeli agricultural technologies and applying them locally. This is manifested in the stream of senior government visits to Jerusalem, innumerable exchange students who arrive for Israeli training programs of different lengths, participation in special workshops and exhibitions and the increasing presence of Israeli firms in Africa.

Often, the events are not linked to Africa per se. For instance, tri-annual Israeli *Agritech* exhibition primary emphasis is on commercial and export sales, with relatively few companies and innovations that appear focused on Africa. Nonetheless, the most recent, 2018 *Agritech* was attended by some 35,000 visitors, some 47 delegations headed by ministers from around the world and thousands of participants from developing economies.[16] African participation was particularly notable, involving thousands of guests from most countries on the continent. Other events, are designed to target high level African government officials to meet the particular needs of the continent. For example, recently, a three-day meeting was convened by Israel's agricultural ministry entitled: "Enhancing Sustainable Agricultural Productivity in Arid and Semi-Arid Regions", attracting ministers and other top officials from thirteen West African states.[17]

Upgrading the yields and profitability of agriculture in Africa, undoubtedly, offers tremendous potential for poverty and inequality reduction. It can offer a sustainable source of income and direct benefits for the most disadvantaged people on the continent. Moreover, seventy percent of the agricultural workforce in Africa are female, who are the major contributors to food production and security.[9] Enhancing agricultural prosperity is tantamount to empowering women.

While few Israeli agrotech startups prioritize the African market, this could change. Dr. Michal Levy, who oversees technology development at Israel's Ministry of Environment is intimately familiar with the innumerable Israeli startups sprouting up throughout the

country. She likens them to “sunflowers” which physically turn in the direction of the sun. In this case, rather than following the “sunshine”, Israeli agrotech start-ups “follow the money”. If incentives could be created to encourage them to target the specific needs of Africa and developing economies, and to offer them a safety net for the associated risks of engaging in this continent, she is certain that it would transform the orientation of these companies.[18]

Recently, on July 23, 2018, Israel’s cabinet passed government decision, No. 4021 entitled: A*dvancing Israeli Activity in the Field of International Development.* The stated objective of the resolution is: “to facilitate realizing the potential that lies in international development for strengthening Israel’s economy and improving its political standing, and in order to expand the State of Israel’s international role. A broad inter-ministerial committee is created and mandated within 120 days, to provide recommendations to that end. Among the committee members are representatives from the Ministries of Economy and Industry, Finance, Agriculture, Health, Environmental Protection, Public Security, the National Economic Council, the Israel Innovation Authority and the Israel National Cyber Directorate.

While the resolution does not specifically mention “agricultural development” it is expected to “encourage the private sector in Israel to take part in international development in order to expand its potential market”. It also calls to support “tools to encourage Israeli innovation for the unique needs of the developing world”. This is supposed to both increase the market potential of the Israeli private sector and to achieve the government’s goals in the field of international development. The committee is to examine possibilities for combining private funding, public funding and funding from international bodies, tools to encourage private funding for international development projects and the possibility of establishing an Israeli development finance institution. Finally, it is to set priorities and coordinate governmental work as well as determine the target countries with whom it should work in the field international development, with “a focus on Israel’s potential contribution to reaching the sustainable development goals defined by the United Nations”.

Israel’s history is replete with cabinet decisions which were never implemented and committees that convened and made recommendations in learned reports that simply collected dust. Yet, experts in Israeli international development policy, like Dr. Aliza Inbal are optimistic, and see the decision as a promising new commitment at the highest level of Israel’s government. It is hard to imagine that agrotech and agricultural assistance will not be at the heart of the inter-ministerial committee’s recommendations.

India and Israel

It is little wonder that in recent years, Israel has come to see India as a particularly important affiliate and consumer for its agrotech products. The sheer magnitude of India’s agricultural sector puts it squarely on any aspiring agrotech company’s radar screen: There are over 263 million farmers in India, with agriculture providing livelihoods to over half of all workers in what will soon be the world’s most populated country. India is already the world’s second largest producer of farm products, with annual exports of agricultural products approaching 30 billion dollars.[19] In some areas such as spices and millet, India already leads the world in production and is among the top producers of wheat.

India is quite cognizant of Israeli agricultural innovations and has reciprocated with a

growing number of joint-agricultural endeavors with Israeli actors. For instance, even though mangos have been grown for 5,000 years in India while only for about twenty in Israel, Israeli expertise was requested for help in growing the tree under water scarce conditions.[20] This win-win nature of expanded agricultural relations was reflected in the recent visits by President Modi to Israel (where naturally he visited the Volcani Institute) and the extended trip by Prime Minister Netanyahu to the sub-continent. Agricultural initiatives were constantly highlighted as part of the itineraries. In fact, the mutual attraction is hardly recent.

Over the course of the past decade, India was the site of the most significant international projects, yet established by Israel's aid agency, Mashav. Mashav agreed to set up some thirty "Centers of Excellence" throughout the vast sub-continent. The financing for the centers is Indian; the expertise in Israeli – from the planning throughout the final implementation stages.[21] The centers have different focuses: one may involve tropical fruits and dates; another flowers and bee production; yet another vegetables and greenhouses. But the basic concept behind the centers is the same: they seek to represent the entire "value chain" in the agricultural cycle, starting with seed development, throughout harvesting and post-harvesting processes and completing with value added products.

The *Centers'* underlying vision is that all farmers in the surrounding areas should have access to the contemporary technologies on display and their applications, with the hope of producing a ripple effect throughout the regions. Ultimately, the *Centers of Excellence* project is extremely ambitious – arguably ambitious to a fault: it seeks to replace existing paradigms with fundamentally alternative, modern approaches to farming. It also assumes that technology offers the most promising strategy for overcoming food insecurity in India.

This orientation has only become more single-minded and intensive as climate change is increasingly recognized as a factor affecting farmers all over the world. Accordingly, the Indian centers pursue an ideal where agriculture will be "weather-free" and where technology will be able to compensate for the anticipated changes in the weather.[22] For example Israeli success in low-cost desalination[23] offers a glimpse of a future of how agriculture can expand when it is no longer dependent on rainfall or limited aquifer capacities. The *Centers* are deemed sufficiently successful to earn a prominent place on the crowded 2018, itinerary of Prime Minister Netanyahu on his India visit.

Thus far, of the thirty *Centers* planned ten years ago, only twenty have been established. From the Israeli foreign ministry's perspective, implementation problems are linked to local Indian administration. That's because Israeli development strategy today is predicated on expecting full "ownership" on the part of the aid recipients -- in this case India. Like so many other countries, Israeli experience is replete with moribund projects in developing countries in which it enthusiastically established based on total-Israeli oversight and technology. When it came time to pass the projects over to local management, there was no one engaged enough to keep them going and they became "orphans".

As a result. Israel requires up-front ownership on the part of India in its projects. Israel serves essentially as a professional consultant: it sends field service agents; its experts offer courses; it exports technologies. But it is Indian staff that build the *Center* and maintain it.

The goal for Israel is to eventually leave these centers fully self-sustainable economically, along with the knowledge they contain for local dissemination.

In 2017, an online, interactive simulation was conducted about Israeli involvement in Indian agriculture. Some forty experts were asked to identify "areas of agriculture where there are favorable opportunities for India and Israel to collaborate in efforts to improve India's food security and agriculture sector."[24]

From the survey, seven key areas were selected and highlighted for collaborative efforts:

- Hybrid seeds;
- Biopesticides;
- Comprehensive Irrigation, Fertigation and Chemigation Solutions;
- Farm Machinery;
- Advice and Knowledge Sharing;
- Resource Management and Precision Agriculture; and
- Post-Harvest and Integrated Value Chains

These areas will be expanded on significantly in the heart of this report.

China and Israel

Israeli engagement in Chinese agriculture began some twenty-five years ago, immediately with the establishment of diplomatic relations. Israeli experts point out that the China that once could use Israel's assistance in the twentieth century is entirely different than today's economic and scientific powerhouse. In 2018, nobody in Israel considers China to be a developing country. After periods of famine and pervasive food insecurity, today China successfully feeds 22% of the world's population with only 9% of the planet's arable land, notwithstanding extreme water scarcity in many regions.[25] This presumably was achieved through a range of policy shifts, in particular de-collectivization and more equitable reallocation of lands in rural villages[26] along with technological advancement.[27]

At the same time, China's population continues to grow as does the demand for a meat-based diet. For instance, over the past decade the country has witnessed a 6% annual increase in consumption of animal feed.[28] To remain self-sufficient, China will need to continue expanding agricultural production at an annual rate of 1% a year in order to produce an additional billion kilograms of grain. It is fair to say that China is highly motivated to upgrade the technological prowess of its farmers and the country increasingly plays a leading role in the world's agrotech sector.

Over the years there have been several Memorandums of Understanding between China and Israel with the goal of spawning agricultural cooperation. These began in 1993 when then foreign Minister, Shimon Peres initiated a Chinese-Israeli International Training Center at the Agricultural University of China. Subsequent agreements mandated cooperation in specific agricultural areas -- from establishing Sino-Israeli Demonstration and Training Center for Agriculture,[29]to sharing post-harvest technologies that extend shelf-life.[30]

Eventually, in 2016, the two countries announced a *Joint Agricultural Action Plan* to ensure that cooperation become more systematic and systemic.[31] Expectations are that agricultural trade between the China and Israel will grow annually at a rate of 25%, bringing total volume

to 450 million dollars by the year 2020. The agreement goes beyond establishment of joint laboratories that focus on genetics, desert agriculture cultivation, animal husbandry and food safety. Of particular interest at present is an Israeli demonstration farm planned for Ningxia. The two governments also agreed to increase trade in produce and food products, as only about 4% of Israel's food products globally are sent to China.

In practice, Israel continues a fairly active program of training, and advanced graduate students from China are common in Israel. Israeli experts are frequently invited to China and host their colleagues as part of these exchanges. By now, China does not receive any Israeli assistance as aid, but rather pays for these services. Indeed, the 2015 acquisition of leading Israeli Dairy Conglomerate, *Tnuva*, by Shanghai-based *Bright Dairy and Food Company* for 1.45 billion dollars[32], reflects the growing Chinese economic muscle and the degree of bi-lateral reciprocity. Israelis working in Africa are highly aware of China's growing presence in the continent, albeit this is perceived as primarily serving Chinese interests rather than a magnanimous act of philanthropy by the Chinese government.

One high profile example of the growing connection between Israeli agrotech and Chinese investment was seen during Alibaba founder, Jack Ma's recent visit to Israel. On his way to the airport and returning flight, Ma visited the Volcani Institute at the Ministry of Agriculture. There he was hosted by its director and the Minister of Agriculture. After a brisk visit through the different departments where he viewed sundry research initiatives, Mr. Ma waxed eloquent about his own interest in investing in agriculture and its importance for China. Needless to say, the reference by such a powerful economic player to the many joint business collaborations that might arise from scientific projects on display, and offer to help in any way in moving them forward, was received favorably by his Israeli hosts.

Summary: Israeli Agrotech's Relationship to Africa, India and China

Discussions with Israeli investors in agrotech suggest that despite its size and the potential market, China is not considered a high priority agricultural sector to serve per se. There are several reasons given for this disinclination. Cultural obstacles are mentioned as a generic impediment to doing business. The size of Chinese farms also tends to be small. Most of Israel's entrepreneurial ventures prefer to work with larger, agri-business clients where they encounter fewer logistical complications and higher profits. Limited by modest financial resources and minimal staff, the typical Israeli agrotech start-up will only become active in China (as well as Africa and India) after their product has gone beyond the "proof of concept stage". There have been occasions when pilot programs have been attempted in China, but this is considered rare. Nonetheless, it seems that there is a slow but steady increased involvement in China and India by Israeli agrotech investors and companies. Efforts by the Indian government to bring smallholders together to make a community-based agricultural intervention are recognized by Israeli agricultural experts and investors as promising and may be a factor in increased involvement in the future.[33]

Amongst Israeli experts, China and India are considered to offer two completely different kinds of markets and agricultural sectors. Generally, China is considered to be more sophisticated and contemporary. Many admirers believe that it is only a matter of time (and not much time – 20 to 30 years) before China begins to dominate the food and agricultural technology markets worldwide. There are other areas in which China appears to be more

"modern". For instance, most of the fresh produce in India is still sold in open-air markets. In China, the majority is purchased in supermarkets. At the same time, India is deemed to be more "transparent" and more Capitalistic, offering Israeli investors a more reassuring environment for doing business. At present, the quality of India's produce is considered to be of poorer quality, even as quantities during certain seasons are prodigious. Indeed, the resulting price can be so inexpensive, that some Israeli experts perceive it as driving higher quality fruits and vegetables out of the market, even in Europe.

In considering Israel's potential role in improving agricultural performance in the developing world, it is well to end with a modicum of humility. Notwithstanding remarkable technological advances, Israeli government leaders are is acutely aware of the country's limitations. Shlomo Ben-Eliyahu, the agricultural Ministry's Director-General explains that if every Israeli was trained to become an agricultural extension agent, and then they all fanned out across India to assist the country's farmers, their numbers would still be such a trivial proportion of the population, that they wouldn't even be recognized as a legal minority. "*Africa also is a very very big place, with extremely diverse conditions. To say that we are going to improve the quality of agricultural research and technology in Africa – seems to me be a bit megalomaniac. Of course, we can take our research (or even technologies developed elsewhere) and try to apply them and see if it might appropriate for specific sites there."*[34]

Conclusion – Helping to Aggregate Small Farmers

In interviewing Israelis in the agrotech world along with farmers and experts who have worked abroad, especially in Africa and India, a perennial problem mentioned in facilitating tech-transfer to smallholders involves "scale": A practical company simply cannot justify the energy and investment required to introduce new technologies and to transfer new protocols and practices to dispersed individual operators. A critical challenge in bringing the potential blessings of Israeli agrotech to Africa, India and China, therefore, involves finding ways to bring individuals together into an operational unit in which both the physical and institutional infrastructure are sufficient to generate higher profits, for all sides.

Here the Israeli market transition constitutes something of a case-study which might be worth considering when considering options and approaches for aggregating smallholders and for creating the networks necessary to enhance their competitive abilities and capacity. In the not so distant past, *Agrexco* was a monolithic exporter of fresh produce for all Israeli farmers. Competition was not allowed, so rival companies went to Israel's Supreme Court that ruled against the monopoly. The immediate unhappy outcome was that innumerable small farmers tried to negotiate their own deals with supermarket chains, yet with little clout, general profitability in the field went down. As *Agrexco's* cash flow situation worsened after exaggerated investment in infrastructure and an office network that spanned the planet, their earnings dwindled.[35] Smaller cooperatives moved in to fill the gaps. Today they represent a middle ground, where farmers can still enjoy a modicum of involvement and avoid asymmetrical negotiations over prices in what is increasingly a global produce market.

One such example is Israel's grape industry. Over the past several years, grape sales in Israel has been transformed by the *Tali* Grapes cooperative. This company, formally founded in 1966 is slowly cornering the market in Israel. With some 66 farms representing 150 families, today the coop today has close to a 50 percent of the domestic market share.[36] With some

thirty grape types, *Tali Grapes* now have a sufficient volume of produce to negotiate prices efffectively with supermarket chains in Israel and beyond. Today, other Israeli grape growers have come to recognize the benefits and are trying to sell their grapes to the cooperative even as they are not members.

In the field of citrus fruits, *Mehadrin*, offers a similar story, where aggregation served to empower farmers who without organizing, would be unable to hold their own in negotiations with retailers. Starting by representing Israeli citrus farms, the company now has access to a range of produce grown on 5000 hectares of Israeli growers. Today it now boast 300 million dollars in sales, with 70% of Israeli produce exports and deliveries to every continent.[37] These aggregation and convergent processes are critical in a country like Israel, where most farm operations are small by international standards. (Indeed, recently a single Mexican grape grower came to Israel to look at new technologies for his 3000 hectares of grape vineyards, equivalent in size to the entire grape crop in Israel.) Because of their high-quality produce and reasonable dimensions, *Tali Grapes* can now enjoy access to the latest in genetic innovations coming out of California. Suppliers would not consider individual farmers simply worth the trouble. The same is true for packaging – with *Tali Grapes* buying the only model of the latest rinsing and packaging machine in Israel.

As the agribusiness world continues forward in what seems like an inexorable march towards convergence, many Israeli experts seem to hold that a sustainable strategy for Africa cannot rely on perpetuating smallholder independence. According to this view, what is deemed to be philanthropic magnanimity in supporting individual farmers may in fact be a disservice. Even if seemingly excessive profits are enjoyed by the agribusiness intermediary, in the long-term, the transfer of technology and knowledge will percolate down and begin to inform the way every farm in the area operates. The workers in a large African strawberry farm operated by Israelis eventually will start growing their own strawberries. Drip irrigation will become commonplace among smallholders, once it is ubiquitous in agribusiness on the continent.

Shlomo Ben-Eliyahu, Director of Israel's Ministry of Agriculture is emphatic on this point. He argues that Israel, does not really know how to influence, teach or maintain smallholders. This requires language skills; literacy about local cultures; understanding the physical conditions and exactly what services are expected These are capabilities that Israelis simply don't have. Presumptions that Israeli interventions can transform the reality of smallholders are dismissed as delusions of grandeur or arrogance. "*But what can we do?"* he asks. "*I think we need to focus on working with the local large agricultural companies and corporations. In many developing countries, these are actually government owned and operated. They have the capacity to apply some of our technologies and will scale them to the appropriate local dimensions. At that point, there is a chance that they might disseminate further. "*

Many private investors share this perspective. Ultimately, Israeli agrotech companies will only become deeply engaged in one of these countries when it identifies a local partner who "knows the ropes" and can offer it access to a broad community of smallholders along with support in moving the new products forward past bureaucratic or social obstacles.[38] In the meanwhile, Europe, US, Canada, Australia and some very large South African farms are considered lower-risk and more profitable venues for promoting new agricultural products.

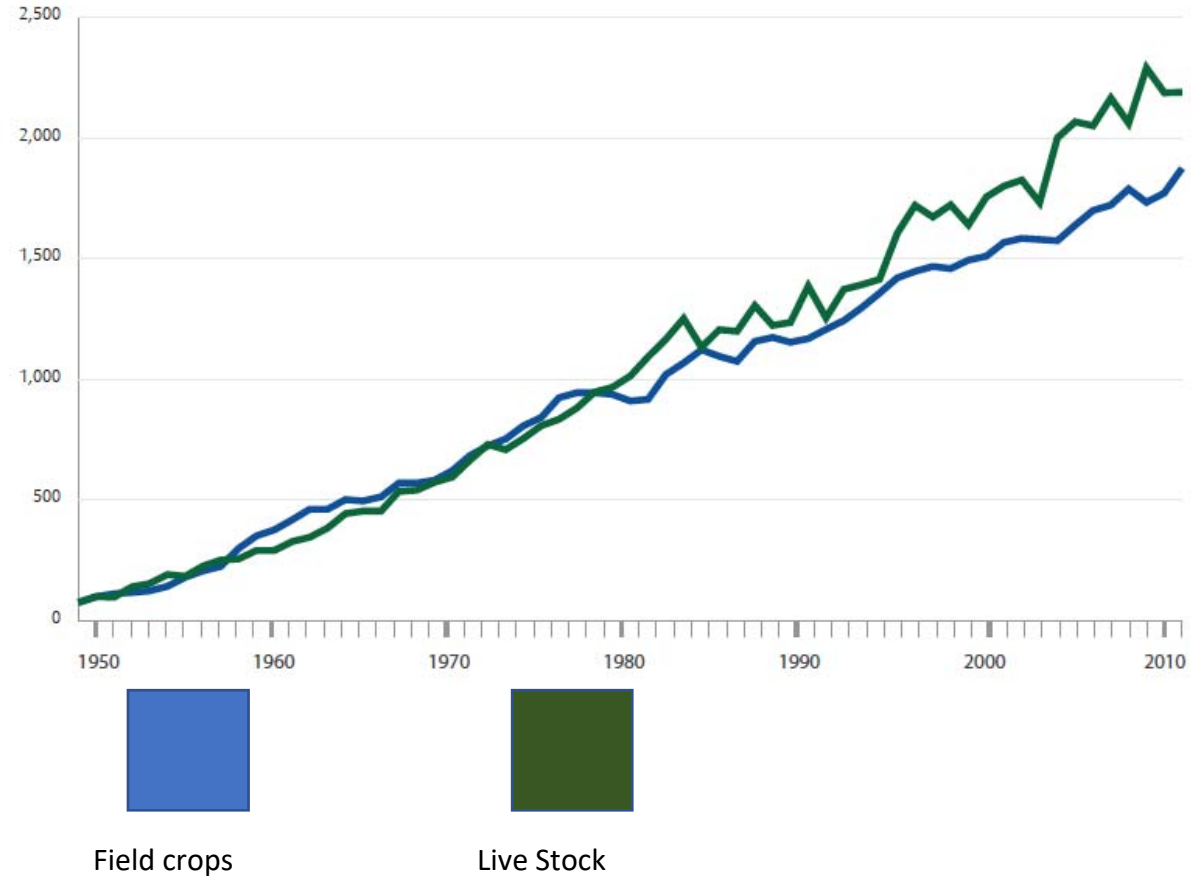
Yet, some Israeli companies and experts with experience in Africa and India are more sanguine.[39] It is possible to mobilize communities and create coop dynamics that produce a market for new technologies. Smallholders can be organized to produce a far greater aggregate capacity, which includes electricity capacity, water management systems, refrigeration, etc. Together, a village can move up the learning curve.[40] But this is unlikely to happen in the foreseeable future without some form of philanthropic intervention.

Part II. A Brief Review of Israel's Innovative Agricultural Sector and Public Policy

Introduction to Israel's Idiosyncratic Agricultural Experience

The rapid expansion of Israeli aggrotech in recent years, in a sense, is a continuation of the country's traditionally ambitious, agricultural vision. The present wave of innovation and progress did not emerge in a vacuum. Rural development and creativity in farming has been prioritized since the advent of the state, 70 years ago.[41] At the heart of the Zionist ideology, which led to the establishment of Israel, was returning to the Jewish people their original status as an agrarian people in their homeland, with a flourishing agricultural sector that could feed a growing nation.[42]

Israeli Agricultural Production, 1950-2010



Source: *Statistical Atlas of Agriculture in Israel, 2013*

This ideology was quickly translated into policies that subsidized water and water infrastructure for the country's farms. A nascent agricultural ministry offered highly professional extension support, protected local produce from foreign competition through import tariffs and supported extraordinary agricultural research. An aggressive "agricultural lobby" was influential, representing the interests of farmers in the corridors of Israel's parliament as well as among key decision makers in the executive branch, such as Israel's Water Commissioner.

For much of Israel's history, the resulting policies were highly effective and produced a steady string of impressive agronomic achievements: Figure 1, taken from Israel's 2013 *Agricultural Atlas*[43] shows the remarkable, steady increase in agricultural yields and livestock productivity over the years, with Israeli farmers essentially redefining the potential of dryland agriculture. The number of agricultural settlements doubled during the country's first forty years to over 700 farming communities, with 562,000 hectares (26%) of the land in the country zoned for cultivation. [44] Roughly 80% of these farm communities are either kibbutzim (Socialist / intentional communities) or Moshavim (private farms with some cooperative, shared facilities.) For a brief period in the country's history, Israel was agriculturally self-sufficient, as its farmers emerged as some of the most highly efficient in the world. This was no simple matter given the arid, semi-arid and dry sub-humid conditions and degraded soils which characterize much of the country's lands. Nonetheless, yields steadily rose and Israel began to export produce at a significant scale.

There are many explanations that can be given for Israel's exceptional success in farming. Some say it goes back to the Zionist ideology which was essentially *ruralist* in its orientation, glorifying the return of the "Jewish farmer" in a renewed Jewish state.[45] Others argue that it can be linked to the egalitarian nature of Israeli society, where farming was not only a respectable profession but a reasonably profitable one. Historically, at least, political leadership was fundamentally committed to the vision of the greater good, which included a robust agricultural sector and relatively little emphasis on personal enrichment.[46] It also was informed by the "can-do", pragmatic culture, born in high school youth movements and then amplified in compulsory military service, where the young people from Israel's agricultural communities emerged disproportionately as leaders.

Israel's farmers and agrotech sector undoubtedly are affected by the pervasive technological optimism, which has characterized Israeli society from the outset, as a European outpost in the Middle East.[47] It was surely part of the early culture of the kibbutzim, that dominated the country agriculturally, and to a lesser extent, politically in the country's early days. Israeli farmers were highly educated relative to international standards. They were restless and open to new ideas. Not only the government, but banks were willing to invest in their new agricultural ideas and ventures which would eventually ripen into the country's present agrotech sector. For whatever reason, it did not take long for Israeli farmers to enjoy a well-deserved reputation for competence and innovation.

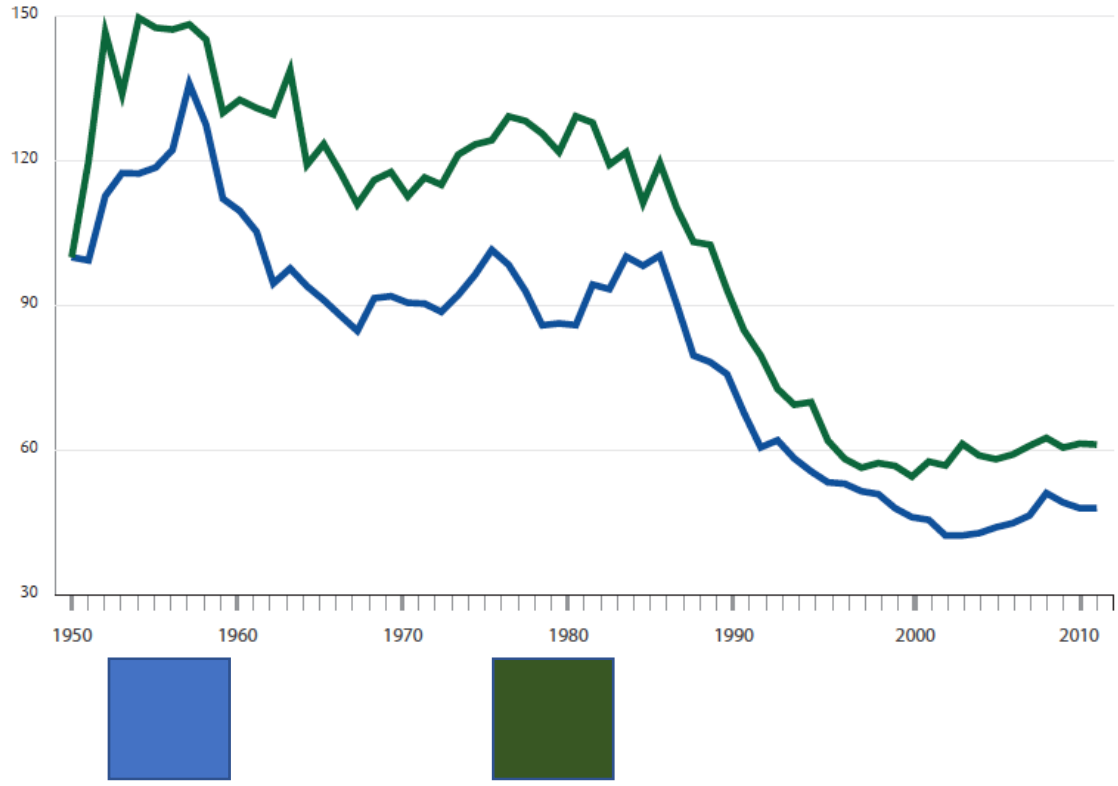
Notwithstanding past and present Israeli agronomic acumen, the country's population was growing far faster than its farms and Israel came to rely on imports to supply its citizens with

sufficient calories to support life. That didn't matter because other sectors of Israel's economy were growing far faster. The domestic product associated with Israel's agricultural sector comes to 7.8 billion dollars, or some 3.3% of GDP. Roughly 18% of the produce grown in Israel is still sent abroad for export, although in recent years competition has grown stiffer, leading to a drop in traditional produce exports to Europe, like red peppers and melons. (Avocados and dates remain an extremely lucrative export crop.)

In absolute terms, Israeli farmers are producing more food than ever, even as the amount of land under cultivation has begun to drop. For much of Israel's history, this efficiency was reflected in the reduction in prices of agricultural commodities in Israel. Figure 2, shows that for Israel's first fifty years, the cost of produce drop steadily (in real terms) over the years. More recently, local demand and food prices have steadily increased, making Israeli markets a compelling alternative for Israel's farmers.

An evaluation by the OECD attributed the progress to increased sophistication and efficiency: *"Growing labour productivity was a key contributor to the almost two-fold increase in total factor productivity in agriculture in 1990-2008, much stronger than in any other sector of the Israeli economy."*[48] In short, the country's steady commitment to agricultural research and development is consistently manifested in higher yields and profits for farmers. Since the year 2004, government expenditures in research and development averaged 17% of the government's agricultural budget. Several government documents emphasize that the future of Israeli agriculture lies in cutting edge agricultural technology.

Price of Israeli Agricultural Commodities, 1950-2010



Source: *Statistical Atlas of Agriculture in Israel, 2013*

In 2013, for example, Israel's Ministry of Agriculture and Rural Development released a new *Masterplan,* which remains the best expression of the country's present agricultural orientation and objectives. The document emphasizes the historic significance of agriculture in establishing the country, but acknowledges that today agriculture makes only a modest contribution to the country's economy. [49] Once, roughly a third of Israelis worked in agriculturally related spheres.[50] Yet, for several decades now, farming provides little employment for Israelis. The number of active farmers in Israel at present is estimated by the government to be only 9,000 to 10,000. At the same time, there are roughly 29,000 foreign agricultural workers, primarily Thai and Palestinian. Some 23,000 additional Israeli citizens are also hired to work in the agricultural sector. Overall, the percentage people engaged in farming in Israel is extremely modest, constituting but 0.5 percent of the country's total workforce.[51]

When the Masterplan was first circulated, it was also the first public acknowledgment by the Ministry of Agriculture that the country was only producing 45% of the calories consumed locally. (In fact, the percentage is far smaller when the contribution of imported seeds consumed via the local dairy and poultry industry are deducted.[52]). Food and agricultural product imports to the country come to roughly 6 billion dollars, accounting for about 7.7 percent of Israel's total imports. These are primarily cereals and meat/fish. A study by Ministry of Agriculture economists projected scenarios for Israel's food security given the 2.1 percent annual growth in population and reached the conclusion that it was practically impossible for Israel to ever be self-sufficient in caloric production again.[53]

Israel is indeed a small country and its ability to grow food for the planet is limited. Officially, the Agriculture Ministry declares agriculture to be a symbol of Israeli innovation and contributor to the local economy. It also envisions local agrotech making a meaningful contribution at the global level: agriculture's primary impact is felt through science and technology. Attributing present achievements to past breakthroughs in agricultural R&D, the agricultural Ministry Masterplan also states that "only entrance into biotechnological and genetic engineering will bring to a meaningful change and a quantum leap to the next phase (in food production)."[54]

It is fair to argue that simply counting the produce grown in Israel understates the Israeli contribution to global agriculture. In terms of absolute produce, perhaps 2-3% of the value of exported fruits and vegetables, internationally can be attributed to Israel. But there are other products and processes that are critical to global agricultural production but that are never counted as agricultural sales in macro-economic indexes. For instance, Israel's drip irrigation exports are usually listed as "plastics"; Fertilizers, seeds and pesticides come under "chemicals"; State-of-the-art greenhouses, designed and constructed in Israel might be listed as "building materials". By one estimate, the total amount of agriculturally related products accounts for something closer to 10% of global markets involving agriculture.[55]

A comprehensive review of Israel's agricultural sector by the OECD in 2010 reached similar conclusions:
"The agricultural sector has benefited from high levels of investment in research and development, well developed education systems and high-performing extension services. Israel is a world leader in many aspects of agricultural technology, particularly those

associated with farming in arid conditions. Thus, agriculture relies not so much on a "natural" comparative advantage in farming, but on an "induced" comparative advantage built on technological progress. The future success of Israeli agriculture and further productivity gains will rely heavily on ensuring an effective system of research, development and technology transfer, and on maintaining well established extension services."[56]

Notwithstanding national pride in local agriculture, as part of Israel's neo-liberal economic perspective, farmers are increasingly expected to be self-sufficient. A significant change in the somewhat paternalistic government orientation towards the sector can be seen in the steady phase out of subsidies and price supports for Israeli farmers and tariffs on food products. Already by 2010, *Total Support Estimates* were significantly lower than the average in the OECD.[57] Free market advocates see this as important for avoiding distortions in trade and resource allocation. Nonetheless, the government remains highly involved in regulating numerous aspects of agricultural production, including water resources and foreign workers.

Moreover, this government phase-out of agricultural subsidies is not absolute. A 2017 OECD review of agricultural policies actually chides Israel for the last remnants of its assistance programs for farmers, which fly in the face of OECD recommendations:
"Despite efforts to implement market-oriented reforms, the persistence of some regulations, price controls and border protection continue to isolate domestic farmgate prices for some commodities from changes on international markets…. Producers of some commodities benefit from market price support, with the largest support for milk and bananas in 2014-16."
This view is not universally held. A recent report issued by the Israel Association for Ecology and Environmental Science argued that more subsidies are actually needed to encourage consumption of healthier foods and produce with a smaller ecological footprint.[58]

Israeli Technological Innovation in Agriculture

Historically, Israel's most profound contributions to agricultural science and technology originated from the need to solve problems. Practical conundrums that arose in delivering water to dryland farms throughout Israel were the key catalyst behind the country's exceptional contribution to improving irrigation efficiency. Seeds were developed for produce with longer shelf lives because the export of fruits and vegetables great distances across the sea became such a central component of local agricultural strategy.

These dynamics, however, are changing. The explanation for many Israeli agricultural innovations today, appears different. For instance, it is not self-evident that progress in the precision agriculture, that is being so successfully developed in Israel today, are a response to a specific local need. Rather there are at least three key, additional cultural elements at the heart of Israel's agrotech ecosystem:

- The historic commitment to agricultural research and the solid academic infrastructure supporting agricultural science and innovation;
- The general societal veneration of innovation and startups which motivates young people (and often not so-young people) to brainstorm and constantly think in terms of creating a new product or company; and

- The wide access to, and familiarity with, a range of technologies developed for and utilized by the Israeli security apparatus that facilitates their application in improving agricultural performance.

For instance, the same drones that provide critical intelligence for the Israeli military can also help support better decision making by farmers. Truth be told, most Israeli farms may not be large enough to benefit financially from the insights and efficiencies that this kind of agricultural technology provides. The potential savings are greatest for farmers cultivating vast plots in places like Iowa or Australia, who stand to gain far more from adding drones to their inventory of agricultural machinery. Nonetheless, the military expertise that its professional staff acquired years ago, helps Israeli agrotech comes out a winner.

This military / agricultural technology connection emerges in the unlikely development of a strategy for controlling the palm weevil (Rhynchophorus ferrugineus). The weevils are responsible for the devastation of entire date groves. For farmers, it feels like a phantom invasion, where one fine day, an entire, seemingly healthy date grove will simply collapse. As pests eat out the trees from the inside of the trunk, it is often practically impossible to identify their presence until the infestation is too extensive and the damage too great.

In recent years, Israel has faced an acute security threat in the litany of tunnels being dug from the Gaza Strip into Israeli territory by the hostile Hamas government, who seek to launch terrorist attacks via the subterranean passageways to kidnap or kill Israeli citizens. A deep barrier is being established around Israel's entire south-western border to physically truncate the burrowing. Sensors were developed that are embedded, below ground, into this new infrastructure that can detect the vibrations of subsurface digging within the adjacent solid soil mass.[59]

Israelis who served in Israel's elite intelligence unit helped develop this technology Although they understood practically nothing about entomology and biology, they immediately realized the potential of such sensors to detect the movement of the weevils as they began to attack date trees. When farmers receive these signals, they know that they need to intervene and start spraying. Results have been exceptional.

Israel's Ministry of Agriculture: Politics versus Professionalism

It is little wonder that Israel's agricultural community makes a clear distinction between the professional staff and the Minister of Agriculture and his political appointees. Whereas in the past, senior politicians vied for the position of Minister and it was considered a lucrative appointment, most recent ministers have had little or no background in agriculture before assuming a position most of them did not really want. As a result, it is not uncommon for ministers to have agendas other than farmers or farming. Often they try to take advantage of the Ministry's budget to further their own political aims. For instance, the present Minister, Uri Ariel, a member of the religious-right party, "The Jewish Home", faces criticism today for directing funds to his West Bank constituents and slashing the agricultural research budget of the ministry by 22% for 2019. By way of contrast, career civil servants in the ministry are typically seen as very supportive and dedicated to finding ways to make farming more profitable. Relative to other ministerial bureaucracies, they are considered to be friendly and flexible, who truly embrace a mission of helping farmers.

Government bureaucrats still have reasonable resources to provide support. The "Investment Center" of the Ministry offers grants for a range of traditional and innovative products. For instance, if a kibbutz needs to purchase new "Cherry Pickers", it can receive a grant of up to 20 to 40 percent of the purchase price. If it wants to expand its fields, the Jewish National Fund, a public corporation will join the government in covering the cost of preparing the field. In Israel's southern deserts, where agriculture is still expanding, this can be a highly expensive proposition, involving land levelling along with purchase and transport of prodigious quantities of sand. Grants can be received for planting new orchards, especially when they contain new crops that the Ministry believes will be profitable. (For example, when they were not yet well accepted by Israeli farmers, subsidies for planting avocado and papaya orchards were made available and were effective in introducing the new crops into the country, eventually contributing to the establishment of these lucrative markets.)

While past agricultural bureaucracies showed some rudiments of cronyism, corruption in present government allocations to farmers appears to be minimal. Applications for grants are filed and approved according to criteria and availability of funding. This makes a real difference in the cost-benefit decision of farm operations as to whether to take a chance on a new venture. Also, farmers are particularly grateful to the publicly supported, regional R&D stations which are perceived as highly pragmatic operations. Unlike universities, the professional staff and their research agendas at the R&D stations are all about the farmers, rather than producing papers that appear in international academic journals.

The Ministry not only supports farmers and farming, but also implicitly includes support for agrotech into its mission statement: "To develop agriculture and establish settlements in Israel to ensure the supply of fresh, high quality food for residents of the state *and to leverage the relative advantage of Israeli agriculture.*"[60] In this context, the unique contribution of its research arm -- the Volcani Institute -- is recognized as an engine for progress in agrotech.

As described below, its government-paid scientists working at *Volcani* have developed a broad range of new crops and innumerable innovations in farming practices. This continues to this day. For example, dates are the largest cash crop in the southern, arid regions within Israel. A new product, "gimmick" developed by Volcani researcher, Yuval Cohen and his team, has recently been developed to slow the growth of trees, which can become unwieldly, inaccessible and dangerous for picking when they go beyond the 20-meter level. This typically can take 45 years, but the new product slows the growth and seems to improve the quality of fruit. Extending the time it takes to reach the 20-meter ceiling by 10 to 15 years constitutes a tremendous savings for farmers.

The Ministry also plays a key role in coordinating pest control measures. Beyond individual assistance to farmers, it takes a-macro role and uses quarantine regulations effectively for pest protection. For example, the red palm weevil *Rhynchophorus ferrugineus* has the potential of devastating palm trees throughout Israel, leading to the disconcerting phenomenon of collapsing palms in the middle of city centers. By preventing the importation of palms into the Arava region of Israel, the agricultural ministry's intervention

has spared the country's largest cohort of date growers the trauma of infestation from this most persistent pest. In addition to innovation in monitoring and chemical control, the Ministry has taken a preventative approach to weevil scourge, relying on the discipline of local farmers. It serves as a national "choreographer" of sorts, directing the genetic quality of life stock, orchestrating the quotas for milk and other subsidized products, promoting more productive seeds and helping farmers to stay on top of the latest innovations.

One of the key political shifts that has taken place in Israel, in this context, is the change in the perceived role and status of the Ministry of Agriculture. The overall ministerial budget is still substantial by Israeli standards: In the present 2017-2018 budget, the ministry receives 340 million dollars for agricultural activities and 571 million dollars for rural development, which includes a substantial budget line for supporting Israel's underprivileged, Bedouin population.[61] Notwithstanding the favorable cultural inclinations, questions have been raised about the adequacy of state support for technological innovation in the agricultural sector.

In conclusion, Israel's Ministry of Agriculture's historic agricultural policies appear to have been largely effective. Israeli farmers still provide Israelis with most of their fruits and vegetables, taking advantage of the generally favorable climate, technological sophistication and economic opportunities. One of the central explanations for the extraordinarily successful collective performance of Israeli farmers lies in the country's agricultural institutional support system, institutions that will be described in the following section.

Policies and Programs to Promote Agricultural Innovation in Israel

In 2012 , Professor Eugene Kandel served as the Chair of Israel's Nation's Economic Council, an elite unit based in the Prime Minister's office responsible for long-term economic forecasting and planning. In considering the future of Israel's agricultural sector, he submitted a series of recommendations, some of which that were eventually adopted, designed to leverage Israeli agricultural successes. Among them, was the suggestion to invest over 25 million dollars in supporting agrotech ventures as well as to establish a senior position to bolster agrotech in the Ministry of Agriculture.

When the position was finally created, it could not have been filled by a better suited expert. Michal Levy completed a doctorate in biochemistry at Hebrew University's agricultural faculty and then did post-doctoral degrees in micro biology at agricultural powerhouse, UC Davis and the Weizmann Institute of Science. Subsequently, she spent five years as a top manager, coordinating at *Yissum*, the "tech transfer" company at Hebrew University—before taking the job of Deputy Director-General for Agricultural Innovation, based in the Chief Scientists Office, at Israel's Ministry of Agriculture.[62]

Although working alongside the chief scientist, Levy's job does not involve research. Rather she sees her mandate as promoting Israel's agricultural start-ups through partnerships with the corporate world, venture capital firms, private investors or anyone who can help scale up the many emerging ideas for Israeli agrotech products and services into profitable, commercial companies. ("I'm more the "D" rather than the "R", she quips.) The program focuses on the "pre-seed" and "seed" stages of new agrotech ventures.

A ten-million-dollar allocation was recently made for her office to oversee a call for proposals promoting agrotech development. Small Israeli start-ups seek large markets, and she tries to help them find them Part of her work involves matchmaking or facilitating the proverbial "B2B" (business to business) interactions. For instance, in the fall of 2018, she is taking Israeli agricultural entrepreneurs for a "road show" to meet with potential investors and partners throughout the United States. Her itinerary includes Iowa, Nebraska, Indiana, California and possibly France.

Notwithstanding Levy's office's recent entry onto the scene, the consensus among people working in the field is that there has been a drop off in state support of Israel's agrotech sector. Ironically, during the 1990s, when Israel was far less of a "start-up nation", there were more aggressive support programs for the tech sector by the government. In the leading program of the period, 100 million dollars was directed to ten different foundations for investments in agricultural technology development. Progress in such areas as Israeli greenhouses, along with the emergence of a few dozen Israeli agrotech companies, are attributed to that round of assistance.

Agrotech in Israel benefits from the generally hyperactive tech sector. Delighted with its successes and global reputation as a Start-Up Nation, the Israeli government has created a formal government framework for nourishing this local entrepreneurial culture. The *Israel Innovation Authority* (Reshut HaChadshanut) is a relatively new agency that operates under the asepsis of the Ministry of Economics. Its start-up division is described on its website as offering: "*unique tools to support the early development stages of technological initiatives These tools assist entrepreneurs and startup companies in developing the innovative technological concepts at the pre-seed or initial R&D stages, transform their ideas into reality and reach significant fundable milestones".*[63] While they have two modest programs in academic research, in fact their funds are prioritized for young Israeli companies or to help foreign ventures to break into Israel.

Relative to other tech areas such as cyber security or biotech, however, historically agricultural products were somewhat neglected in the funding they received from the *Authority*. Levy believes that this is because for the most part, there were no "jaw-dropping" breakthroughs that would could "wow" government bureaucrats with transformative innovations. By way of example, a start-up company might aspire to develop a robot that can pick tomatoes. This task tends to be one of the less edifying harvesting experiences in agriculture. It is also a complicated technical challenge that requires image processing, identifying ripe fruit and picking it without causing damage. But a tomato-picking robot doesn't involve a completely new way of thinking about or solving a problem.

As a result, in the allocation of public funds, agricultural entrepreneurs were simply ranked lower than their colleagues who came up with more revolutionary, hi-tech ideas. After the Ministry of Agriculture established its *Agricultural Innovation* department in the Chief Scientist's office, assessed the situation, it suggested that the criteria be expanded: *innovation* alone would not be the sole determinant of a product's worthiness for public support, but also *impact.* An automatic tomato picker could transform an entire branch of agriculture and have a profound impact without producing meaningfully new scientific achievements.

Levy's program recently funded a new call for proposals that it is implementing via the "Innovation Authority". In this new round, "impact" will be integrated in the selection criteria.[64] This improves the possibility that smallholders might benefit from the new ideas produced by Israel's agrotech ecosystem.

The Israel Innovation Authority

The Israel Innovation Authority is a significant government player, supporting Israel's tech program in general. With an annual budget of grants close to 500 million dollars, its staff of 150 government workers and 180 external technical reviewers processes hundreds of requests for support. By design it does not seek out potentially profitable ventures but receives grant requests through tenders which are meticulously reviewed.

Technically the Authority does not offer loans, but describes its support as "grants". This is precise assuming that the company developing the product fails. But in the event of success, the entrepreneur is expected to pay back the grant in full. Nonetheless, the Innovation Authority provides a critical "safety net", allowing new companies to take chances without the same kind of risks that a Bank loan might entail or the dilution that a VC might expect. The Authority also has a series of "bi-lateral" programs, run by its international division which is designed to allow for expanded economic involvement and opportunity for investment from other countries.

Agriculture per se is not prioritized by the Authority. Their two basic criteria are the same across all programmatic areas.

1) The level of innovation; and
2) The potential profitability.[65]

One small program, overseen by the Innovations Authority, is in fact targeted to the challenges of developing countries: the "*Grand Challenges"* competition. A joint initiative with Israel's Ministry of Foreign Affairs, the program offers ten, half-million shekel (135 thousand dollar) grants to support "innovative ideas helping resolve Global Health Issues and Ensuring Food Security".[66] Much as the Innovations Authority is happy to use its seasoned review and oversight infrastructure in partnership with the Foreign Ministry, it is open to joint ventures with philanthropic institutions who wish to develop technologies designed to improve the quality of life (and agricultural yields) in developing countries.[67]

Overall, while Israel's government is extremely proud of the innovations that have emerged in the area of agricultural technology, the remarkable achievements are not a result of a focused and fervent promotional policy. *Trendline's* agrotech start-up maven, Nitza Kardish is frank in her evaluation of the Ministry of Agriculture's checkered policy in the field of agrotech*. "Eugene Kandel and his committee made some clear recommendations six years ago about bolstering agrotechnology in Israel. It is not clear to me how much has actually been implemented. But at the same time, there are definitely more "listening ears" in the government when we talk about agrotech's potential. But I surely can't say that there's a coherent policy that is organized and a strategic orientation."*[68]

The Agritech Exhibition

An important contribution to the Israeli agrotech ecosystem comes is made by the Israel *Agritech* exhibition, held every three years in Tel Aviv. Technically, the exhibition is run by a non-profit organization, that hires a commercial company (*Kenes*), to run the three-day extravaganza. The exhibition was originally sponsored by the now defunct mechanization department at the Ministry of Agriculture. As *Agritech* expanded and became more successful, the project was eventually spun off as an NGO, whose board is comprised of natural institutional partners. The first exhibition, some forty years ago, was held at the Mikveh Yisrael agricultural school on the southern outskirts of Tel Aviv. But the event soon outgrew this venue and for some time now has been held at the Israel Trade Fairs and Convention Center in Tel Aviv.

The May 2018 event was the 20th *Agritech* exhibition. The 15,000 attending international guests were almost double the number of those who came to Israel for the previous, 2015 fair. The considerable investment by local companies in their exhibition stands suggests that the event constitutes an important opportunity to reach thousands of potential buyers from around the world and that the meeting place indeed catalyzes many important deals. The *Agritech Association* has recently decided to establish a permanent exhibition, returning to the original Mikveh Yisrael site, which will serve as a year-round "gateway" for visitors interested in agricultural technologies, as well as an educational center for Israelis.[69]

Ofir Libstein is the volunteer chair of the Agritech Israel Association, alongside his "day job" as farm manager at Kibbutz Holit. Libstein explains that *Agritech's* goal is to provide exposure to Israeli companies that produce technologies and services for the international market. Although there are international companies that display products at the event, this is mostly a concession to the commercial company's profit motive and the need to cover expenses. Concomitant to the exhibition and the "dog and pony shows" offered by a broad range of exhibitors, Agritech Israel hosts a scientific / policy conference which offers lectures from experts, local and international, on a range of relevant topics. One of the sessions in the 2018 conference focused on technology for assisting smallholders in developing countries. Nonetheless, Libstein acknowledges that despite its importance, products for smallholders are a somewhat neglected area at the exhibition. Libstein is optimistic about the tremendous potential that the smallholder market represents. He believes that the market is approaching a "tipping point", when the enormous available profits will drive a new wave of innovation for this cohort among Israeli companies.[70]

Private Sector Investment and the Entrepreneurial World of Israeli Agrotech

Given the relatively numerous and robust tech mutual funds operating in Israel, there are relatively few VCs that target them prioritize investments for agricultural technologies. Among the leaders is *Green Soil investments.* This Ra'ananah-based venture capital firm already has six major investments and is in the process of raising an additional 30 to 50 million dollars. It seeks to provide funding to promising start-ups that have passed beyond a proof of concept stage and need to move into a more mature phase of development. Generally, the company seeks "Round A" or "Round B", rather than seed or pre-seed investments. As a rule of thumb, *Green Soil Investments* directs 80% of their funds to Israeli inventions and startups and only 20% to new ventures in other countries.[71]

Another player is Herzliyah-based *Copia Ag. and Food*, which specializes in working with academia and bringing their ideas to the market.[72] The company is essentially a "technology transfer" company, that generates resources to support ideas that emerge from scientific research, until they ripen sufficiently for industrial application. The company initially raised 25 million dollars to help launch twelve agrotech projects which it believes have significant potential impact. Its largest single investor is Altshuler-Shacham an Israeli pension fund manager. Individuals from Japan, the U.S. and Europe also "bought in".[73]

Many observers suggest that the major "missing link" in Israel's agrotech ecosystem today is actually not at the "start-up" stage, but actually soon thereafter, when a product seems promising but needs some more financial muscle to transition into a significant production phase.[74] Present *accelerators,* they argue, do not have the budgets to provide these "adolescent" companies the money they need to blossom into a significant producer and employer that can begin exporting to the world.

Jacob Mualem Marom, Director of *Kidum,* the Volcani Institute's commercial development arm, describes what he sees as a four-tiered process in the agricultural/food entrepreneurial cycle. At the top of the triangle are the giant, multi-national corporations who control the vast majority of world markets for agricultural inputs. This includes some forty multi-billion-dollar corporations like *Unilever, Bayer, BASF, Dupont Monsanto* and *Syngenta*.[75] Typically an Israeli agrobusiness start-up will seek to develop a product that eventually will be purchased by one of these major players. In an ideal scenario, this might happen through a four-stage process that includes: a) Proof of concept, scientifically; b) proof of economic concept; and c) product development that can lead to d) acquisition of the product dissemination via one of the multi-national giants. Accordingly, stage c constitutes the weak link in the Israeli chain of agrotech development. A schematic triangle of the four stages is depicted as figure 4.

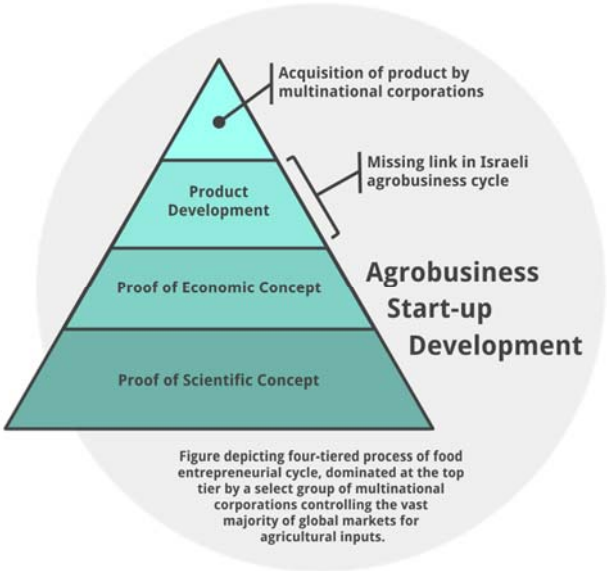


Figure depicting four-tiered process of food entrepreneurial cycle, dominated at the top tier by a select group of multinational corporations controlling the vast majority of global markets for agricultural inputs.

Recently, the chief scientist of Israel's Ministry of Agriculture, Professor Avi Pearl, has attempted to address this challenge by launching a new initiative: "Nitsan", which the

Ministry often refers to affectionately as “Noah’s Ark”. The program brings together companies with researchers in academia who have a promising idea that is at a “proof of scientific concept” stage. The program provides most of the funding for three years, but expects that as time goes on, the companies will increasingly contribute to the product development and have “skin the game”.[76] During the first year of the program, a sponsoring company is not asked to invest anything. In the second year, convinced of the project’s value, the company contributes 10% of the project cost. During the third year, the required contribution is raised to 20%. While still in its early stages, this sort of a public private partnership might provide some of the bridge to fill in this missing link.

There is no shortage of good ideas among Israeli scientists and the local incubator and VC networks, the Ministry of Agriculture’s “Nitsan” etc., have begun to provide an early home to the fledging operations as they aspire to become compelling economic options. The problem, again, involves that critical the third stage. Michal Levy, who oversees the agrotech development process for the Israeli government, agrees that when an Israeli agricultural start-up begins to envision its long-term strategy, its ultimate goal – which she tries to facilitate – is to create a product that will be appealing to one of the top tier, multi-national giants.[77] To the extent that those companies include smallholders among their target commercial markets, Israeli entrepreneurs will be better focused on meeting their particular needs and consider their capacity.

In some cases, the support system for Israeli agrotech start-ups are just not enough, and promising ventures are wooed abroad. For example, *Yarok Technology Transfer Ltd*. could be a poster child for the Israeli agrotech start-up world. Its product provides fast and accurate testing of food products, receiving a 2017 award for “Innovative Ideas and Technology in Agribusiness” from UNIDO ITPO. The contest seeks “the world’s most innovative technologies and ideas in agribusiness to improve the socio-economic, food safety and security conditions in Less Developed Countries” and is convened in conjunction with the United Nations Organization for Industrial Development,

The Jerusalem-based start-up was selected as one of five winners among the 330 entries from eighty competing countries.[78] *Yarok* indeed offers a critical service, especially for developing countries where in the absence of refrigeration, food safety constitutes a paramount challenge: Within 45 minutes, its system can indicate the presence of food contamination (such as E.coli, Listeria, Salmonella, etc.) to ensure that fresh produce is safe for consumption. Pilot units are successfully operating in Italy and Israel.

Its CEO, Jonathan Sierra, immigrated to Israel years ago from Italy and began to gravitate to the new opportunities in agrotech. During his initial endeavors, he made every effort not to bring on additional partners and dilute ownership excessively. But now he realizes that he has reached a stage where in order to scale up, investors are a necessity. Unfortunately, Israel did not offer as compelling an environment for moving the company to the next stage. So, he has set up shop in a Swiss accelerator after winning the prize and commutes regularly from Jerusalem. In Israel, he would have had to pay rent, while in Switzerland he is both receiving a fellowship *and* his company enjoys free accommodations. When asked about the motivation behind the Swiss magnanimity, he explains that they want to learn from the

Israeli start-up passion, so that Switzerland can begin to develop a comparable entrepreneurial culture.[79]

It is not clear, however, whether the Israeli model is something can be easily imported. Israeli agrotech start-up culture remains idiosyncratic. It is also decidedly modest in dimensions. This is not limited to the agricultural sector. While there are an innumerable creative, ideas explored in hi-tech, Israel has produced relatively few of the so-called "unicorns" (privately held new companies that are valued at one billion dollars or more). Israeli entrepreneurs tend to prefer fast, certain exits with less lucrative buyouts than patiently waiting for a company to mature. Of course, there are conspicuous exceptions that prove the rule (*Mobileye* that was sold to *Intel* for 15 billion dollars; *Waze* that was purchased by *Google* for 1 billion dollars.) The prevailing assumption among Israeli agrotech entrepreneurs remains that their pilot projects will be far more successful under the patronage of a large, multi-national corporate sponsor or partner.

In general, Israeli agrotech entrepreneurial cultural appears to be similar Israel's general start-up culture which has been fairly well documented.[80] For example, while in many countries, launching one or two failed start-ups would be considered something of a disgrace, disqualifying someone from future entrepreneurial ventures, Israel remains very charitable to new ideas from inventors and entrepreneurs who tried but did not succeed in starting a new company. There are many "serial entrepreneurs in Israel's general tech sector (e.g., Waze founder Uri Levine, who after exiting immediately went on to develop other apps like *Zeek*, a marketplace for unused store credit) Agrotech also has its indefatigable heroes. For example, physician Isaac Bentwich,[81] is associated with CropX (irrigation sensors) success; or Hebrew University biotechnology Professor Oded Shoseyov, whose work in nanobiotechnology, protein engineering, and plant molecular biology have produced a variety of commercial processes and nano-cellulose products.[82]

Part III. Israel's Agricultural Research Institutions

When Israel was created, its population doubled within a decade.[83] To address the rampant unemployment and housing shortages, new agricultural communities were created to absorb the recently arrived refugees. But most of these new farmers lacked even minimal experience in agriculture, much less raising crops and livestock in dryland conditions. To address these dynamics, Israel's incipient agricultural bureaucracy quickly established a support system for local farmers that continues until today. This three- tiered system has been jocularly referred to as the "Holy Trinity" and is frequently cited as the key to Israeli agricultural success. The three institutional tiers include:

a) Basic and applied agricultural research at universities and the Ministry of Agriculture's Volcani Institute;

b) A network of eight regional research and development centers serving farmers across the country; and
c) An extension service (Sha'ham -- based on the Hebrew acronym for Technical Advisory Services) of 150 agricultural field workers, in addition to a small army of advisors who assist farmer in meeting the challenge of plant protection. [84]

University Researchers

Scientifically Israel's academic centers are at the top of this pyramid. Israeli universities hold the twin advantage of extremely low-cost, high-quality graduate students, along with professors, whose wages are already covered by the government. For the most part, they can take on ambitious research projects with relatively modest grants, with no need to cover their own salary expenses. Also, Israeli universities are happy to partner with African institutions of higher learning. That means that basic research and agrotech development in Israel can serve to empower scientists at major universities in countries like Ethiopia, South Africa, Kenya and Tanzania.

The country's two central research institutions in agriculture are the government sponsored, Volcani Institute and its affiliated facilities along with the Faculty of Agriculture of the Hebrew University at its Rehovoth campus. In addition, valuable research is conducted at the Faculty of Life Sciences at Tel Aviv University as well as the department of Dryland Agriculture at Ben Gurion University's Sede Boqer campus and the Agricultural Engineering department at the Technion, Israel Institute of Technology.

Since its inception Volcani Institute has had more agricultural researchers than all the other Israeli institutions put together. The Institute is divided into three different facilities: Volcani Institute headquarters, located near Tel Aviv at the Beit Dagan campus, is also home to the Ministry of Agriculture's central offices; a southern research instillation at Gilat; and a northern research center at Neveh Ya'ar. The professional staff at the three centers are in constantly communication and take advantage of the enormous professional and climatic contrasts between their locations. For instance, a good example of their long-term cooperation involves collaborative research about net houses that considers the effect of colorization on the internal micro-climates, the quantity and quality of yields, timing of ripening as well as reduced pesticide and water usage.[85]

The Institute's 100 million-dollar annual budget supports some 200 Ph.D. level researchers and their teams of technicians and graduate students. Some 60% of the Institute's funding comes from the government and another 40% from research grants received by its scientific staff. Institute Director, Professor Feinerman points out that the percentage of funding received by the government is actually lower than Hebrew University, which receives 65% of its budget from public funding.[86] In order to encourage staff to pursue external funding for their research, a significant component of the Institute's funds is allocated as matching support for competitive research grants attained by the Institute's staff. About a third of the overall budget goes to support individual research projects; a third is directed to the Institute's different research units; 25% covers the expenses of administration and management and 10% is designated for the "patent fund" which is overseen by Kidum, the commercialization arm of the Institute.[87]

The Institute is held in high regard throughout Israel, including political leaders who are not directly involved in agriculture. During Indian Prime Minister Narendra Modi's 2017 visit to Volcani, Israeli Prime Minister Netanyahu introduced the Volcani Institute as "the best agricultural research institute in the world". Realizing that this might be a bit hyperbolic, Netanyahu corrected himself and said, "Well, I surely don't know of any better agricultural research institute".[88]

In recent years, there has been a far greater emphasis on applied research that can produce a commercial project. In a 2018 report, Rotem Zelingher reports an impressive and steady increase in the number of patents for agriculturally related inventions developed at the Volcani Institute.

	Number of Patents Attained	
Years	Israeli	Internationally
1970/74	4	0
1975/79	6	3
1980/84	17	6
1985/89	27	33
1990/94	13	21
1995/99	32	12
2000/04	35	56
2005/09	25	38
2010/14	30	71
2015/17	29	61

Even though almost all of the Volcani researchers have studied at some point at the Hebrew University Agricultural Faculty, the two institutions appear to be at odds and the institutional rivalry is not always constructive. Indeed, dozens of senior researchers from the Ministry of Agriculture's Volcani Institute, serve as adjunct faculty for the Hebrew University graduate program, many serving as thesis advisors. The present Director of the Volcani, Institute, Eli Feinerman, was actually a full professor at the Rehovoth campus who was recruited away from the Hebrew University. Nonetheless, observers note that researchers at the two institutions "always appear to be bickering", with the dynamic compared to the rivalry between the Israeli army's tank brigade and the air force.

Recently, an independent American advisory committee was invited to come to Israel and offer an objective assessment about the performance of the two research institutions. When asked to assess the possibility of greater division and separation between the two institutions, they were unequivocal in their view that reducing Volcani's role in the Faculty of Agriculture's program would be a very bad idea. The evaluation highlighted the synergy historically produced by the cooperation.

Government Sponsored Research

Professor Eli Feinerman serves as Director of the Volcani Institute today after many years as an eminent professor of agricultural economics at Hebrew University. He explains that the

Institute has a challenge in maintaining its status as solely a research institute due to the fairly relentless requests for advice and assistance for practical problems at the field level. For instance, the same day that Feinerman was interviewed for this report, he was approached by medical personnel from Uganda where there is a quiet epidemic of diabetes, presumably due to the high carbohydrate content of cassava (a common root vegetable, also known as "tapioca"). The visitors wanted to know: "Could the Volcani Institute help create a higher protein vegetable?" Frequently, a powerful economic player from a developing country who owns enormous tracks of land will ask for the Institute to help plan an optimal agricultural strategy for a new agribusiness development.

Like his predecessors, Feinerman is careful to avoid pressures to turn the institution into a high-level extension service. He is also well aware of the likely push back from the researchers if there should be a move in that direction. Nonetheless, there is certainly a need and a niche for a high-level team, with access to the knowhow and scientific personnel at the Institute to help Africa and other developing countries with their practical problems. Feinerman's inspired proposal is to create the equivalent of an "international extension service" comprised of Volcani retirees. As Israeli law requires government workers to retire at 68 – there is a large cadre of extremely experienced knowledgeable, vigorous and idealistic scientists who could easily be convinced, through modest remuneration, to take on projects in developing countries. The remarkable work done in Senegal and much of West Africa by the late, "semi-retired professor" Zev Pasternak stands as a model of senior Israeli academic's potential impact [89]

In retrospect, Pasternak's success has a great to do with his stamina and persistence. CINADCO director, Yaakov Peleg, who oversees Israeli assistance to developing counties, points to innumerable examples of failed projects in India, China and in African. The absence of a prolonged, Israeli presence led to discontinuation of critical practices, commitment and ultimately disrepair .[90] Ministry of Agriculture Chief Scientist Avi Pearl explains that not any qualified scientist will do. Rather he believes, that an Israeli scientist who comes to promote a project in the developing world needs to have "lightning in their eyes", boldness as well as Western management orientation. If the initiative not considered a "life project", it probably won't succeed.[91]

This view is not universally held. For instance, Dr. Avi Pearl, the Chief Scientist at Israel's agricultural ministry acknowledges that there is untapped expertise among Israeli retirees. But he believes that there is a world market for agricultural assistance and that the private sector should provide the framework for utilizing such talents, if indeed there is a genuine need for them. CINADCO director, disagrees that the market can provide a solution. For example, certain areas of expertise are simply not money-making ventures. He gives the example of seed storage and management in times of crisis as an area where existing expertise lies almost completely among publicly employed scientists and practitioners. He argues that there should be a government role in sharing this expertise with the world.[92]

But bringing veteran, Israeli agricultural experts to Africa is not envisioned in the context of scientific research, but rather solving problems as glorified extension agents. As matter of policy, Israel's Ministry of Agriculture does not prioritize research with African partners. Ministry Chief Scientist Pearl speaks with surprising candor on this point. "*In the past, I tried*

to create tri-lateral research initiatives that would focus on Africa. We were specifically talking to the government in Germany as well as France, along with an African partner – like Kenya. For example, we were interested in upgrading the genetic makeup of the wheat grown there, something which could contribute considerably to their yields. Let's be clear: the developing country was not expected to put any money into the initiative. Their contribution would be giving the research team access to local, endemic strains of wheat.

But then, there were problems. First some technical /legal problems which the European countries faced. And then there was the more fundamental question of the African scientists. When you enter into a scientific collaboration, it has to be a synergy where one plus one equals three. It was never clear who the scientific partner was going to be in the African country. I don't see scientific research there as having great potential, even though as a ministry we would like to assist Africa. Joint research, however, is probably not be the best way."[93]

This view is supported by his boss, Shlomo Ben-Eliyahu, the agricultural ministry director. Noting that it usually averages from seven to twelve years between the initiation of research until an actual, commercial product is available, he believes that the present problems don't need fundamental, breakthrough research – but application of existing knowledge, practices and technologies to local conditions in the developing world in order to provide immediate solutions.[94]

The private sector, however, sees things somewhat differently. Dr. Nitza Kardish, a veteran, Israeli agrotech developer challenges many of the prevailing assumptions at the Ministry of Agriculture. For instance, the prolong timetables for developing a promising technology seem to be exaggerated. She points to several examples of Israeli agrotech companies that became operational much faster. *Biofishency*, for example, an "all-in-one water treatment system" for increasing the fish productivity of and reducing the environmental impacts of aquaculture systems,[95] became operational within three years and began sales around the world, including China and Africa. *Eden Shield*, which offers a plant-based wash that provides nontoxic protection from insects[96] was selling products after three years. In its fourth year, its products were already reaching distributors in China, Brazil, Mexico and north Africa.[97]

In her opinion, both of these companies, are also examples of agrotech start-ups whose products could be extremely beneficial for smallholders in Africa and beyond. While there are many Israeli agrotech ideas which are less relevant to smallholders, Kardish believes that there could be far greater engagement between the agrotech entrepreneurial world and the smallholder market in Africa, China and India. What is needed to move the present modest dimensions of smallholder targeted agrotech in Israel is a significant source of financial support that would encourage ideas that are accessible and valuable to small farms in the developing world

Kardish has no illusions, however, about the motivations of Israeli agrotech entrepreneurs. "*I'll be straightforward with you,"* she explains*. It's not sustainability or taking care of the world that moves a start-up. It's about making money. Many of them come from the hi-tech world and they are looking to get their next app up and running and to make an exit."* A public interest driven investment fund with a global perspective that offers a safety net for

start-ups targeting the problems of smallholders could make a difference. But she cautions against expecting this kind of proactive support from a government source in Israel: Thus far, it is the private sector that transformed the Israeli agrotech start-up world; its engagement will be necessary if the agrotech sector is to go beyond its present markets and reach the developing world.

Regional Agricultural R&D Centers

Supplementing the scientific capacity at Israel's universities and the Volcani Institute, the second tier of assistance is provided by a network of eight regional R&D centers. The centers' budget generally comes from government budgeting, funding from the Jewish National Fund (a public Zionist corporation) and grants received by local researchers. These mid-sized field stations serve as a bridge between farmers' on-site needs and the ever-evolving scientific knowledge and technological innovation. The centers have proper laboratory facilities, hire agricultural specialists and also compete for competitive grant proposals. They are frequently staffed by experienced farmers, rather than doctoral level scientists.

Some of these applied R&D centers are credited with making substantial technological breakthroughs.[98] For instance, the researchers at the Arava R&D enter played an important role in developing the "family drip" systems which rely on the low surface tension in smooth plastics. Generally, however, these Field Centers are not places where new crops or technologies are developed. Rather, it is here where plant and cultivation techniques are upgraded and the problems which have been encountered in adopting new farm practices are solved. For example, the Medjool date, originated in Morocco. But the fruit was significantly improved as a commercial commodity at the southern research stations in Israel, with quantum leaps in yields, based on systematic evaluations and adjustment. R&D Centers' work creates technical advancements which are more *iterative* and *incremental* than *transformational*. For example, this might involve extending the shelf-life of a fruit or developing optimal irrigation protocols.

R&D Centers typically have an academic director who is a Ph.D. researcher associated with a university or the Volcani Institute. This expedites cooperation between his/her colleagues in the academic sector and the R&D staff and farmers in the field. Indeed, the partnership between the university researchers and the R&D staff is a classic win-win dynamic: The R&D station get to partner with internationally renowned scientists, while the academic researchers benefit from highly competent field staff, that know local conditions and provide a reality check for their work.

Field Extension Agents

The next institutional tier, working exclusive with farmers, is Israel's extension service. While its numbers have dropped significantly over the years, Israel's Ministry of Agriculture and Rural Development still fields a formidable team of highly professional extension agents. All have formal training in agriculture and they maintain a steady communication with the top academic centers as well as the R&D centers. Israeli farmers see the system as critical for maintaining existing operations. Additional, more specialized assistance is provided by the staffers of the "Plant Protection Service" who not only regulates pesticide registration, but helps farmers identify pests in the field and appropriate chemical or biological responses.

This expertise is considered essential for addressing pest problems in real time, with ”24/7” access to experts, ready to respond to an infestation of insects or mites before they get out of hand.

The historical effectiveness of Israeli agricultural extension service’s work can be attributed to several factors. It starts with the level of Israeli farmers, who often have extremely advanced training themselves and have been self-selected for being innovative and meticulous. Avi Pearl, the Chief Scientist at the Ministry of Agriculture refers to the “Advantage of Smallness”. In a country where no geographic distance is prohibitively long, it is easy for extension agents to pass information along and to see the results on-site. As the farming community is fairly tight-knit, they can share their experiences easily. Finally, Israeli extension agents are highly motivated. Not only is the quality of local extension personnel in developing countries considered problematic, but also their enthusiasm. Part of it is not their faults. If they are lucky enough to have a motorcycle, they probably don’t have funding for petrol or money to fix it. [99]

Israeli experts who have worked on agricultural ventures in other countries, including Arab nations like Dubai and Jordan, have come to appreciate the role of Israel’s extension agents. They describe international assistance projects where local practitioners were trained in Israel. Then Israeli experts arrived to help establish a certain facility or crop. But all too often, results are disappointing. In the face of sandstorms, pests, viruses and ever-mounting salinity, without resources for ongoing maintenance and access to experienced professionals to help farmers make speedy and informed management decisions, projects quickly collapsed.[100]

While Israeli farmers are relatively open to new ideas, some researchers express polite criticism of the Ministry of Agriculture. They argue that the Ministry has not been sufficiently proactive in promoting new technologies in recent years. Present subsidies that might grant Israeli farmers the safety net required to be “early adaptors” are deemed inadequate, and *technology forcing* regulatory measures extremely rare.

Sometimes farmers circumvent their local extension agent and make contact directly with a university professor or other experts. For instance, farmers feel free to call Dr. Eli Fallik, an internationally renowned expert in post-harvest crop protection from the Volcani Institute. It is not uncommon for Fallik and his colleagues to receive telephone calls at all hours of the night on their cell phones at home, requesting help in solving a problem. (Even foreign farmers who happened to hear a lecture from Fallik at an international workshop have been known to call, texting photographs of problematic leaves or crops, to receive his sage advice.)

No area of ongoing assistance is more important than pest management, with Israel having unique experience in dryland agriculture. Confronting the vast infestation of pests, which inevitably appear as new agricultural operations emerge, constitutes both a scientific and a logistical challenge. Farmers who began farming in Israel’s Arava valley during the 1960s and ‘70s, initially only needed to address the problem of one type of fly and one insect in their pest control efforts. Slowly but surely, the number of flies that were attracted to the new agricultural operations.

For example, the *Tuta absoluta* was a well-known moth whose decimation of tomato crops was only known in South America. But by the 1990s, the pest had spread to numerous European countries until eventually reaching the Middle East.

Tuta absoluta, a relentless and devasting pest for tomatoes and other crops.

When the *Tuta absoluta* made its first Israeli appearance, local farmers turned to the academic community for advice about controlling the moths. Experts were highly pessimistic about the prospects, especially when the local farming community decided to opt for a strategy that utilized biological controls. Applying "SIT" – Sterilized Insect Techniques, with the full cooperation of the facilities at Israel's Soreq nuclear center, some 500 traps in the Arava were positioned so that that the pest population could be mapped and monitored via a GIS mapping system.

The intervention has been viewed as a breathtaking success. But in pest management, there are always new "bullets to dodge'. Even as the market for organic produce is growing in Israel, it is hard to find farmers or agricultural researchers who are sanguine about solving all the problem without some chemical applications. *Rhynchophorus ferrugineus,* the red palm or Asian palm weevil is such case. This particularly persistent snout beetle has seen its range grown throughout the Mediterranean region and is considered a major threat for present productivity. Without the constant assistance of the Ministry of Agriculture's pest control experts, the task would be all but impossible.

There are additional benefits from this network of agriculture research and expertise to the country's economy beyond improving agricultural yields. A growing number of agrotech ventures are spawned by the innovative research at universities or the experience of farmers and farm communities at the field level. The following section, and the primary focus of this report, describes the origins and dynamics of the Israeli agrotech scene. It then assesses a broad range of these companies with unique abilities to make meaningful contributions to improvement of smallholder agriculture in Africa, India and China.

Part IV. Israel's Agrotech Ecosystem

Israeli Agrotech's Inspiration, Composition and Orientation

There are numerous possible explanations behind Israel's constant and exceptional level of innovation in agricultural technologies. The most obvious one is *necessity*: for many years, Israel's agricultural communities' economic viability has been dependent on exports. This means that there is a constant need to compete with the new crops and practices developed in Spain, California and Australia. The general sentiment is: "If we don't continuously bring something with added value, we'll be out of business." So, there is always incentive to do better.[101]But motivation alone is not sufficient for success.

The expansion of Israel's olive industry offers a case in point. Olive trees have been part of the local, Israeli landscape from time immemorial. But for most of Israel's history, it was considered a traditional crop of the indigenous Arab community. Once the world became enamored of the many health benefits associated with olive oil, the Israeli Agrotech sector began to take notice. It took roughly fifteen years for the dramatic results to be seen. Yields from Israeli olive tree were increased several fold and tree density increased dramatically. This reduced the expenses associated with maintaining an olive grove. And now scientists are moving ahead improving the olive crops by breeding asymmetric particles into olives. This allows one side of a particle to be hydrophobic and the other hydrophilic, expanding the possible qualities of the olives as well as their antioxidant potential.

There are presently close to 500 active Israeli companies working in the agrotech field. Twelve of them were established before the country gained independence in 1948.[102] But over a quarter of these are less than five years old; half were founded within the past decade. In 2017 some 160 million dollars was raised by investors, an increase of 65 percent relative to 97 million raised in 2016. On average, roughly 500 million dollars have been invested annually in Israeli agrotech industries over the past several years. This represents a significant share of related international investment. In, recent years, the percentage of global investment in Israeli agrotech increased from 4% to 7% of total global funding. This may seem like a modest share, but then Israel is home to only 0.1 percent of the world's population. On a per capita basis, this is 2.4 times greater than U.S. investment in the agrotech sector.[103]

Tamar Weiss, oversees the agro-food tech sector at *Start Up Nation Central*, a Tel Aviv-based NGO, with sixty skilled analysts. The organization serves as a clearinghouse of information, and an intermediary between Israel's hi-tech sector and potential investors. She explains that in contrast to areas like cyber-security where Israel's tech economy has flourished, there are three key areas of technology where Israel is underperforming. These are: *Agriculture; Digital and Health.*

Investor confidence in agrotech has been validated several times in recent years. In just four years, ten "exits" (primarily acquisitions) garnered total sales of some 600 million dollars. The recent acquisition of an 80% of *Netafim* by *Mexichem* involved a 1.5 billion-dollar deal. Some 120 significant investors in Israeli agrotech have been identified: roughly half involve local Israelis and half international. At the same time, relatively few Israeli Venture Capital

firms prioritize the agrotech sector.

Weiss describes a highly diverse Israeli agrotech sector, which ranges from genetic modifications to post-harvest and seed improvement. With such a broad range of interests, it is little wonder that companies in the agrotech field, especially start-ups, rarely interact. *Start Up National Central* is interested in creating a platform for such communications, cultivating an "ecosystem" where cooperative ventures can produce synergistic results.

At present, the Israeli agrotech sector is expanding, providing jobs for 18,000 workers, taking advantage of the societies, skilled and educated elite. To be sure, salaries, for agrotech workers are still 25% lower than hi-tech and roughly half of the most lucrative tech sectors, such as cyber security. Yet, for the foreseeable future, the sector should be able to rely on a reasonable reservoir of highly trained, local talent. There are roughly 1,100 students studying in agriculture at Israeli university, 600 of whom are in graduate programs. This constitutes roughly 1% of Israel's student population.[104](The Central Bureau of Statistics reports that the median age of undergraduate applicants to agricultural programs is the highest of any degree (~24).[105]) This reflects the very high percentage of Jewish citizens among the applicants (92%) and the relatively modest percentage of Israeli Arab citizens who are not drafted to military service. As it turns out, the vast majority of Israeli agriculture students are military veterans.

Israeli Agrotech's Human Capital and Incubators

Institutional frameworks and human capital still need to be developed to continue to produce new ideas and improvements. In Israel's agrotech sector, many of the workers bring skills from STEM fields other than agriculture (e.g., computer programming, civil engineering) with some 40% coming with academic backgrounds in the biological or biomedical sciences. Some 60% of agrotech workers are former army officers.[106] But the sector has not expanded to the extent that other areas of technology (e.g., hi-tech; cyber security, etc.). This may be due to the fact that new agrotech ventures typically have a longer "gestation" period than do other areas. This affects the thinking of venture capitalists. Nonetheless, global agrotech has seen dramatic increases in investment, increasing 600 percent (from 0.5 to 3.2. billion dollars) in the five years between 2012 and 2016. Technologies that promote better decision making by farmers constitute a particularly popular area of investment. For instance, "Smart Farming" has received the lion's share of support for new Israeli agrotech ventures.

Perhaps an important, human resource question is: who are the entrepreneurs in Israeli agrotech today? No one has evaluated more agrotech projects and shepherded more Israeli agrotech ventures forward than *Trendline* incubator CEO Nitza Kardish. She estimates that roughly half of Israel's agrotech ventures come from its academic communities – the Volcani Institute and the universities. The other new ideas come from creative kibbutz and moshav (small farm) members; former military intelligence and computer personnel, and seasoned hi tech developers, who see an opportunity in the agricultural world market.[107]

Technological incubators offer a relatively small, but important organized framework that can provide support these agrotech startups in Israel. The incubators originally operated

through the licensing of the Chief Scientists of the Ministry of Industry and Trade, and have recently transitioned to be part of the new Innovation Agency, an independent agency created by Israel's government. Accelerators are designed to help manage and accompany investors in start-up companies during the initial stages of their development. According to the model adopted by Israel's government, 85% of the funding for the new venture are provided by the state – with corporate participation set at 15% by the licensed incubators.

Pursuant to the model, in practice the state takes responsibility for most of the financial risk associated with the new companies. Once a new venture begins to have revenues, it begins to pay back the money that it received from the state, under extremely comfortable conditions and interest rates -- far lower than those offered by commercial banks. The new start-ups are not expected to pay back sums in excess of 3% of their total revenues, so that the payments can take many years to complete. Moreover, the new start-ups enjoy the benefit of a support team of advisors, professionals and support-staff that assist them on an ongoing basis. The time spent in the incubators by start-ups is characterized by relative emotional and economic stability and calm, allowing entrepreneurs to focus on developing products rather than chasing funds to pay back loans.

Startups are automatically allowed to stay in the technological incubators for a two-year duration, enjoying direct financial aid of up to 850,000 dollars. Certain kinds of initiatives are entitled to an additional 125,000 dollars. In return for their initial investment, investors who back the product early receive from 30 to 50% ownership in the company with the government receiving 3 to 5% of the earnings that are eventually generated until the initial loan is repaid.

Dov Rekoni, the CEO of the Nelson Incubator, emphasizes the general importance of incubators to Israeli industry as a critical catalyst in the agrotech ecosystem. Much of the success in startups and innovation in Israel can be attributed to these programs, which are supported by the Israel Innovations Authority, (formerly – the Office of the Chief Scientist at the Israeli Ministry of Industry and Trade). The Authority is chaired by the Chief Scientist of the Ministry. Prudent investors can receive a handsome return, with a relatively modest investment in agrotech ideas, at this stage in the process. Today there are some 20 technology incubators working in Israel. An initial incubator overseen by *Trendlines,* focused exclusively on agrotech: "*Mofet in Judah Ltd. – the Periphery Incubator*, in the South Hebron area, funded by the *Trendlines* and other companies, although it ceased operations some six years ago. Today *Trendlines* with *Yahin Impact*, which focuses on products that prevent food loss. Other Israeli incubators focus on biotech and other products which are related to agriculture.

A recent evaluation of funding by *Startup Nation Central* shows that funding for Israeli Agrotech is provided primarily by venture capital firms (46%), "angel funds" (23%); corporate investments ((18%) and only 5% from incubators. Moreover, some 3% of the agrotech startups receive their first capital through internet crowd funding platforms.

Trendlines – the Original Israeli Agrotech VC and Incubator

One of the most important private sector players in Israel's agrotech ecosystem is *Trendlines Group.* Dividing its efforts between medical and agricultural technologies, on its website,

Trendlines describes itself as an innovation commercialization company: *"Trendlines invents, discovers, invests in, and incubates innovation-based agricultural technologies."*[108] The company was founded by two American businessmen, Steve Rhodes and Todd Dollinger, who brought their considerable business experience with them to Israel. The two have since served as company chairmen, and CEOs. With its headquarters in the Galilean village of Misgav, *Trendline* has some 40 employees with significant operations recently established in Singapore.

The *Trendlines Group* agricultural program got off the ground when Nitza Kardish joined the team nine years ago Kardish began her training early, graduating from the Mikveh Yisrael, agricultural high school. As Israel's oldest boarding school, this Tel Aviv area institution has been introducing adolescents to the science and practice of farming since 1870. Kardish went on to complete her Ph.D. in plant science and a post-doc at the Weizmann Institute. She then began work on the business end of new medical technologies, and for fifteen years was based at the Klal Corporation and later at the Technion's commercial development branch. Eventually, her original agricultural impulse resurfaced, and she joined forces with the *Trendlines* group, overseeing creation of Israel's first agrotech incubator. Today she serves a s the VP of the Trendlines Group and as CEO of their incubators in Israel.[109]

With the rapid ascent of Israel's hi-tech sector, Kardish was convinced that bringing these types of innovative technological solutions to agricultural practices held enormous economic potential. It took her a year and a half to convince the government to embrace the concept of an agrotech incubator. At which point she began to scour the country for promising ideas. Seven years later, the *Trendline* agricultural incubator in the Etzion Block near Jerusalem can be called an unqualified success. The incubator supports companies in the R and D stages, helping them in the transition to becoming independent companies. Every year the company invests in between eight and ten new ventures, choosing from the roughly 500 startups that it evaluates.[110] The company's track record, thus far, is impressive: *Trendlines* can point to the establishment of 23 companies: 5 of which closed, but 18 are in various stages on the continuum towards commercial independence. Recently, the company established a joint venture capital fund with the international corporation, *Bayer*.

Trendline's present portfolio reflects an extremely broad range of ideas and places on the agriculture value chain. For instance, a sample of some of the new companies it helped spawn includes:

- *Hargol,* which optimizes methods for efficient growing of grasshoppers;
- *Fruit Spec,* which offers precise estimates of fruit tree yield while still at the green stage, *IBI AG*, a new biological pest control company;
- *Metomotion* and its robotic system for reducing labor in vegetable production in greenhouses;
  MiRobot, an automatic robotic milking system; and
- *Valentis Nanotech*, Innovative coating platform for food packaging.

As part of her work in *Trendline,* Kardish also started Israel's annual *Agrivest* conference, which has emerged as one of the world's four largest business gatherings that focuses on food and agricultural investment.[111] The first *Agrivest* meeting had 80 participants; this year's May gathering in Tel Aviv brought together a thousand from around the world. The

center of attention is the competition for the "Best Israeli Agtech company". Unlike the nearby *Agritech* exhibition, which is a trade show that typically hosts a range of government and agriculturally oriented delegations, *Agrivest* is a place to do business, attracting venture capital investors from around the world.

Case Study: Kidum R and D Applications

A completely different kind of player in Israel's agrotech world is *Kidum R and D Applications.* To expedite commercialization of its scientific findings, the Volcani Institute established *Kidum* as its entrepreneurial division. *Kidum* boasts a team of over eleven staffers, almost all with MBA degrees. There is a complex formula for division of the revenues generated from its development efforts: after paying the direct costs for the product development, patent, rights, etc., most of the funds are divided three ways, between the Volcani Institute Management, general research funds and the relevant researcher(s), who can receive a bonus. *Kidum* maintains a small fraction of profits for its operational expenses.[112] It is worth noting that the "bonus" which a Volcani researcher actually receives for a successful agrotech development is extremely modest relative to their colleagues. In the Weizmann Institute, for example, an entrepreneurially savvy scientist can enjoy 40% of the profits associated with a new agrotech product.[113]

Heading the operation is Jacob Mualem Marom, who comes to the position from the business end and only recently has become fluent in the vagaries of agricultural technology. But he is a quick study. Mualem Marom explains that generally, the research conducted at Volcani leads to products and practices that are valuable at the high end of the agricultural sophistication spectrum ("the tip of the tip" of the peak.). In other words, if a farmer doesn't have access to basic infrastructure, such as refrigeration, most of the Institute's innovations are not relevant.

Given *Kidum's* role at the Volcani Institute, it is no surprise that Mualem Marom believes that while the new products developed can surely help developing countries in general, and Africa in particular, any exchange needs to be primarily designed on a solid "business basis", without philanthropic dimensions. He argues that countries that are relatively "less developed", such as Indonesia and Thailand, have been able to utilize new technology from Israel and that all sides made money. Moreover, Israeli technology, has helped several of these developing countries improve their balance of trade payments, by strengthening their agricultural export sector. If the ultimate objective of a venture is not economic, then the prospects of it being a sustainable are dim.

To truly empower smallholders, he believes that they have to reach efficiencies and economies of scale to compete. "I'm not saying that they have to start exporting. But it's simply not enough to say to a farmer in Ghana: 'we'll help you grow cocoa.' They have to be able to incorporate the technology." Moreover, no less important than new technologies are protocols for these farm operations: *how top pick the crops without damaging them, how to treat the water; preserve the soil.*

Mualem offers numerous examples of successful tech transfer: Flower growing in Israel used to be a very big money maker. But today, Israeli flowers are hardly grown…. in Israel. You will, however, find enormous fields of flowers growing from Israeli seeds in Vietnam,

Columbia and Africa, raised by Israeli businessmen and their local partners. Israeli tree nurseries are doing well in Africa. The same is true for strawberries, mangos and avocado. According to Mualem, the reason they are succeeding has to do with the quality of the produce. Because of the farmers' enhanced ability to sell high end produce to international super market chains, they can enjoy prices as much as 300 percent higher: from 30 euro cents per kilogram, a fruit or vegetable can jump to 1.1 euro.

As a businessman, Mualem does not recommend investing directly in smallholders. Rather he prefers a strategy that identifies a promising, major player in the agricultural marketing sector, who can help organize the smaller farming units and represent their interests at the market. This will provide them with access to higher productivity seeds and practices as well as to more efficient technologies.[114]

Although *Kidum's* perspective is informed by the "bottom line", maximizing profit does not seem to be the unit's paramount objective. In that sense, *Kidum* reflects the organizational culture of the Volcani Institute. For instance, the Institute gives out its new seed types to all Israeli farmers for free. Most of these seeds are developed for dryland conditions in Israel which con fundamentally different qualities than the high-yield alternatives commonly sold in Europe and North America. For instance, the Volcani Institute has developed new wheat seed varieties that could potentially transform yields in Egypt, Tunisia and Iraq.

Mualem Marom explains that he would like to find a way to give away most of these innovations to Africa, if a "symbolic one-time fee" could be arranged to make it, at least ostensibly, worthwhile. He also would like the recognition that the technology and new innovation came from Israel. "Our country invested heavily in developing these products: it should at least be recognized". As just one of many examples, he points to "mulchline", a new line of crops developed by Volcani researchers, whose yields on steeply-sloped fields are roughly three to four times higher than conventional crops. The benefits for African farmers are so compelling that he feels obliged to share them. Ideally, this could be done through collaboration with an African partner.[115]

Hebrew University's *Agrinnovation*: From Academic Insights to Marketable Products

Taking the findings from basic research at university laboratories to create a useful and economically viable agricultural product constitutes a classic challenge for both economists and increasingly opportunistic university administrations. A very recent development at Israel's Hebrew University offers an interesting model for engaging scientists and turning them into agrotech entrepreneurs. It took a veteran hi-tech executive to make it happen.

After over twenty years as a senior, start-up executive, Ido Schechter decided it was time to come home to academia. The son of a former president of Haifa University, he completed his doctorate in Canada in the area of plant physiology and worked overseeing fruit tree cultivation in Ontario before returning to Israel. Schechter then briefly worked as a researcher at the Volcani Institute. But with Israeli hi-tech looking for local talent, he was soon wooed away. In 2015, he saw an opportunity to integrate his twin professional passions.

Israel's universities for some time have tried to improve their precarious economic situation by creating fully-owned subsidiary companies that commercialize the research of their faculty. This has the potential to be especially lucrative in in certain areas such as pharmaceuticals. The Hebrew University's entrepreneurial wing was established as "*Yissum*". But it soon became clear that *Yissum* was doing very little to promote the myriad "agrotech" ideas that were emerging from the university's Rehovoth-based Faculty of Agriculture. It opted for a strategy of licensing professors' ideas with commercial potential to outside companies. In retrospect, such partnerships produced only de minimis income – as the licensing agreement typically left the university with only a 2 or 3 percent return on any profits that were generated.

Schechter proposed a more aggressive and more promising framework. He created a new fund: "*Agrinnovation*" which would be owned in half by the university – and half by the investors that he would recruit. As CEO, Schechter also took on the job of shepherding the projects through the different stages in the commercialization process: from an idea, to concept to product to market.

His initial notion was to raise 30 million dollars in venture capital. But he quickly realized that he did not yet have enough viable projects to justify that level of investment and settled for a 6 million-dollar pool for *Agrinnovation's* launch. The results appear to have exceeded even his own high expectations. Within two years he produced eight compelling projects, several of which are moving to "stage A", and the establishment of independent companies. About half of the new ventures involve nutrition.

Getting the Hebrew University professors to think like entrepreneurs was a gradual process. Coming from the hi-tech culture, Schechter tried to focus on what were the real problems that needed to be solved. The natural inclination of an academic is to look at their research results and then point to innovative solutions to problems, whether or not they are germane from a commercial or agronomic perspective. *Agrinnovation* also offered them funding of up to half a million dollars to develop promising ideas with minimal paperwork -- an unimaginable sum for most Israeli academic researchers.

One of Schechter's takeaways from the experience is that the real breakthroughs in agrotech come from interdisciplinary cooperation. Creating such dialogues is relatively easy to do at the Hebrew University Agriculture Faculty with its stable of 95 diverse researchers. His call for proposals actually found its way beyond the Faculty: one of the more intriguing proposals that *Agrinnovation* decided to pursue came from a professor of physics. It envisions a creative way for consumers to assess the relative freshness of packaged fish.

Among the ventures that has advanced most quickly from *Agrinnovation's* work is an antibiotic control for livestock. The automatic inclusion of antibiotics in food to farm animals to increase herd resistance to disease is a well-recognized phenomenon and reflected in numerous water samples near factory farms. The aggregate result is massive exposure of humans to antibiotics in food supply with the net effect of reducing the efficacy of standard antibiotic treatments. The American Food and Drug Administration has already identified this as a public health problem and begun to intervene, requiring individual vaccinations of animals in response to identifiable illness, rather than the blanket

medicating of entire herds. The problem is that like people, farm animals don't particularly like taking shots. After the first injection, animals often resist additional treatments. For some domestic pets, like cats, it's ineffective to apply antibiotics orally.

A team of Hebrew University veterinary and pharmaceutical experts worked to create an antibiotic treatment that can create a slow, "linear" release injection for standard antibiotics like moxypen (amoxicillin). The measured release saves time and money, allowing for a more efficient medical intervention where dosage can be ensured and release gradually. The prototype inoculation was designed for pigs, who because of their intelligence tend to be particularly tough to corner for a second injection. But the strategy proves just as effective for the range of agricultural and domestic livestock. The product came to be called *the Florfenicol One Shot Controlled Release Concept* or simply: "FFC". In another project, a hi–tech engineer, working with an etymologist, found a way to protect plants from aphids by exposing them to a field of low level radiation (comparable to that emitted by a cellphone) which drives away the pests.

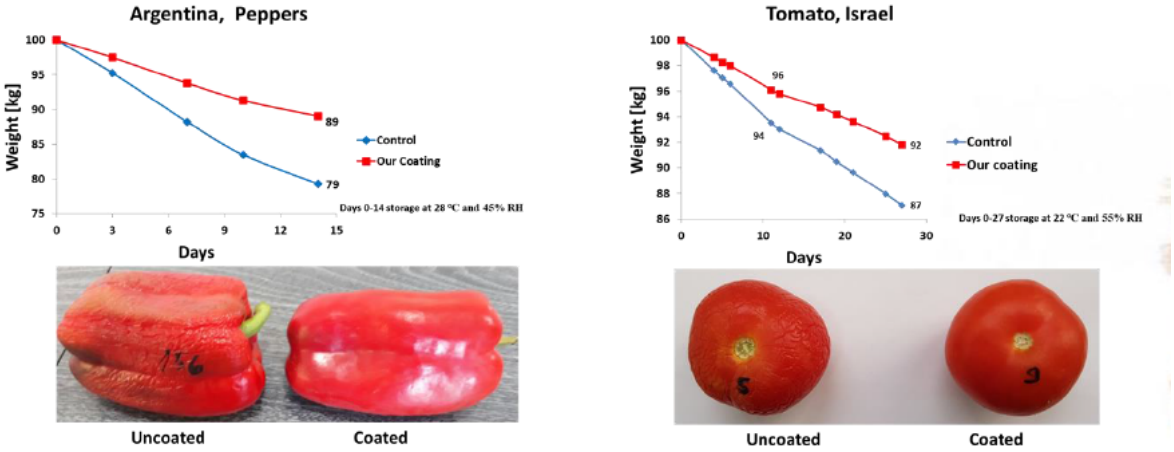
Some of the new Hebrew U./Agrinnovation may be especially valuable for developing countries, especially Africa. Two in particular are singled out: Working with experts at the University's Department of Nutrition, a chickpea protein distillation process was designed. Typically, non-animal protein comes from soy beans, an additive found in innumerable processed foods in Western diets. But there are complaints that soy brings with it a range of problems: some claim that it is allergenic for many people and can cause chronic inflammation and an itchy throat; it can block digestion of protein by the body; it has been shown to raise the risk of heart disease; it is known to exacerbate gas; and when it is grown, it is typically sprayed with round up (glyphosate), a possible carcinogen.[116]

Agrinnovation's new product already has a product name: *Chick P.* The brainchild of professors Ram Reifen and Shimrit Bar El, the chickpea distillation process has already been patented, gone through the first round of investment, and is ready for market implementation. The process takes 100 kg. of humus and produces 20% of a 90% chickpea protein. Beyond its low fertilizer demands, *Chick P* claims a rich variety of benefits including lower cholesterol, increased protein digestibility as well as freedom from gluten/lactose/egg and GMOs. Perhaps most important, Africans are already keen chick pea growers. Indian farmers, already dominate the market, with 60% of world production. The new product could be critical to solving a basic nutritional conundrum in developing countries where carbohydrates are often available but there is a chronic scarcity of proteins.

The second promising product involves "high-end fruit and vegetable coatings". Professor Amos Nussinovitch faced the challenge of finding a healthy generic coating that could extend the shelf-life of vegetables. Marketing specifications required that it be comprised of organic materials without any synthetic chemicals. Nussinovitch eventually settled on bee's wax as the primary component of the coating and called the product "Sufresca". Bee's wax, has the advantage of being a seal, but with enough permeability to allow for fruit respiration.

Peppers were a natural place to start for assessing the coating's efficacy. Because they are filled with air, the decomposition process begins quickly. Trials showed that when peppers

were dipped in Sufresca, it extended their shelf life by 3 to 3.5 weeks. Tomatoes, garlic, even avocadoes all responded well -- with two weeks of additional viability after being coated. Figure3, taken from an Agrinnovation promotional brochure, shows the advantage of coating with the new product, both visually and quantitatively.



In Africa, where smallholders have practically no access to refrigeration and half of the crops never make it to consumers or even the market, this additional window of time is critical. Because China's enormous fleet of trucks typically have no cooling capacity, investors there are particularly interested in this new low-cost, low-tech, post-harvest treatment.

Schechter is extremely encouraged by the growing engagement of his formidable dream team of academics and their initial forays into biotech. He is defying them to take on new challenges. For example: can they produce apples that don't turn brown? One team is well along in developing a contraption that can report the percentage of THC in a cannabis plant.

Part V. Israel's Agrotech and Smallholders

There is one thing that Israel's many agrotech companies have in common: only *rarely* are products developed that are particularly appropriate for African farmers and designed to address problems they face. For instance, the local press became excited at two recent agrotech startups; robotic sonar for yield assessments developed at the Volcani Research Institute[117] and a tiny, wireless solar-powered tag, developed by Sol Chip which enables the autonomous operation of a variety of agricultural sensors.[118] These are clever and highly sophisticated gadgets which can surely improve the efficiency of advanced agricultural operations. But they would probably be useless for most African smallholders.

There are three reasons which can be attributed to this gap. Firstly, Israel's somewhat sophisticated agricultural practices offers a natural point of orientation for Israeli startups. There are profound differences between the reality for farmers in Africa and Israel. Secondly, the minimal economic capacity among Africa's agricultural community is seen as offering companies a very modest potential market. With a few exceptions, the likelihood that an Africa smallholder farmer can pay for an innovative Israeli products or services is

low. If there is a clear subsidy available, committed lending agency or an effective cooperative effort for an African community, the relevance and economic calculus for Israeli innovations could improve.

The third issue involves the problem of cultural acceptance for Israeli agricultural technology among smallholders in developing countries. Weiss believes that this aversion could easily change with successful marketing and extension support in African countries. For instance, in recent years Israeli agrotech companies have altered their perceptions about India, increasingly seeing the country as a potential target for marketing, even though in the not too distant past, it was also considered to be an unattractive market.[119]

It is important to remember and highlight Israel's historic involvement as agricultural advisors in Africa. It seems that there is a fundamental difference between the Israeli agricultural academics or even technical emissaries who often engage in African challenges and the economic agrotech sector. The former group of experts are frequent visitors to Africa and have made enormous contribution to local agrarian initiatives. Individuals like Dr. Dov Pasternak, whose work in introducing modern irrigation and commercializing dozens of new varieties of fruit trees and vegetables in West Africa, remains the subject of admiration (in and outside of Israel).[120] For sixty years, scientists and farmers have brought Israeli knowhow to the continent, providing valuable advice and agronomic strategies. In contrast, Israel's agricultural technology companies, especially the start-ups with little margin for error, do not see a high likelihood of ever receiving regular payments from African clients with cost-benefit calculation for targeting African farming communities coming out negative.

This is unfortunate, as much like India and China, agricultural entrepreneurial initiatives in Africa are growing rapidly. With a more focused orientation on African markets, Israeli agrotech companies could create innovative solutions for the unique circumstances facing smallholders in the continent.

Israeli Perspectives on Agricultural Interventions in Africa

Since the 1950s, a large number of Israeli experts have been engaged either as formal government emissaries or in more private capacities in providing on-site assistance to African farmers. Israeli universities increasingly offer their students opportunities to visit Africa in the context of agricultural assistance. For instance, at the Sdeh Boqer campus of Ben Gurion University, water Professor Noam Weisbrod, Director of the Zuckerberg Institute for Water Research has for many years run a summer course for graduate students where they join African NGOs in implementing hands-on water projects: One class went to Ethiopia to drill boreholes water and installed low-tech water pumps to provide drinking. In Uganda, other students built a rain catchment system near school bathrooms.[121]

The impressions formed by agricultural professionals during their time, on site, in African countries undoubtedly informs the thinking as they perform the basic research behind the country's aggrotech industry. But most Israeli professors in biological and agricultural sciences have never visited Africa. Increasing the opportunities for such visits may be one way to increase the "smallholder" applications coming out of the Israeli agrotech ecosystem.

Israel's global outreach program to assist farmers internationally in general and in Africa in particular, is coordinated by Mashav. Mashasv is a Hebrew acronym for The Agency for International Development Cooperation and is a branch of Israel's Ministry of Foreign Affairs. Established in 1957 by then Foreign Minister, Golda, the department's primary focus historically has been establishing training programs that allow Israeli experts to share their knowledge with visitors from developing countries in a range of areas. Although Mashav's budget has always been modest, its resources have become even more depleted over the years.[122] Nonetheless, Mashav has managed to effectively leverage its limited funds impressively, as well as mobilize Israeli diplomatic staff stationed in developing countries. For some time, senior management at Mashav has prioritized agricultural outreach to Africa and has sponsored several initiatives with varying degrees of success. Over the years, countless Israelis have spent time in Africa working on agricultural projects at the initiative of the foreign ministry.

Part of the difficulty in expanding Israeli engagement with African farmers is the lack of a reliable local partner. For the most part, African national governments still are unable, or disinclined to make significant investments in their agricultural sector. For instance, in 2010, out of the 44 African countries for which data are available, only 9 have reached or exceeded the target of allocating 10% of public expenditure to agriculture.[9] That is why almost every Israeli interviewed that had some experience working with African agriculture agreed that international aid and philanthropy are imperative to increasing its local agricultural capacities. Even so, all too often assistance via NGOs to Africa's farmers is ill-advised.

The history of agricultural aid in the continent is quite literally littered with the debris of Israeli equipment from projects that were established by well-meaning experts, but which lacked a long-term strategy for lasting economic sustainability. Those with experience in the area identify three key areas where assistance is needed to improve the capacity of Africa to overcome the syndrome of ephemeral progress:

1) Knowledge, including the kinds of technologies and practices that are discussed in this report;
2) Credit to ensure the necessary inputs and agrotech practices required to move beyond subsistence farming; and
3) Access to markets.[123]

Knowledge is critical at every stage in a country's agronomic transition. For instance, as an area increases yields and begins to transform itself agriculturally, it becomes a target for pests with which the local community is often unfamiliar. If an agricultural extension presence is not created, with the ability to address these kinds of problems in real time, years of progress and well-designed projects can soon collapse. Local farmers may end up worse off than they were prior to the support and intervention. Israeli agricultural researchers are quite unified in their conviction that simply providing seeds or an irrigation system is a waste of resources. Even smallholder farmers need to learn a range of critical skills that may involve soil sampling, optimal irrigation timing, etc. They also need help in finding parts and then fixing broken equipment, like pumps, when they break.

Clearly, part of the challenge is sociological rather than agricultural. Israeli experts, who have been effective in establishing projects in African, stress the need to become fully acquainted

with local communities. They emphasize the importance of understanding local cultural and existing agri*cultural* inclinations *prior* to launching farming initiatives there. Given the need for long-term engagement, donors need to make sure that initiatives are based both on a technology and a strategy that is effective for the specific circumstances and constraints facing a given local community of smallholders.

Some agricultural researchers question the viability of applying the Israeli experience to developing countries altogether, especially in Africa. Gilat researcher Alon Ben-Gal is one of Israel's leading, international irrigation specialists. Ben-Gal is particularly emphatic on this point: "Success in one place in no way guarantees you success elsewhere. In Israel, one of the reasons that we are succeeding is because the economics work. Farmers are not driven so much by the desire to feed the world but by a profit motive. It's not calories but dollars that are driving the system. My impression is that this kind of model is not appropriate for Africa." Chief Scientist for the agricultural ministry, Avi Pearl uses a metaphor to make the same basic metaphor. Agricultural is not always a "copy-paste" dynamic. He explains that many agricultural technologies are not like brakes that you can install in any car, be they in Africa, China or India. Rather you have to understand local conditions and adjust the solution to the prevailing local environmental and social conditions. Adaptive, maintenance-driven research is required. It's not a "copy-paste" dynamic.[124]

Israeli agricultural researchers and entrepreneurs all seem to be keen about lending a hand to development efforts in Africa. At the level of lip service at least, the consensus is exceptional. At the same time, there is a strong agreement that Israeli researchers and even their assistants cannot assume the role of *extension agents* in helping to establish Israeli technologies or farming practices in Africa. Their limited time and resources for such efforts are obvious as is their predominant commitment to research -- and not philanthropy. On the other hand, the consensus also seems to be that it is entirely feasible to expand existing training programs, whereby African extension agents might come to Israel or attend workshops convened locally in Africa. Agronomists and agricultural engineers working with other developing communities could also benefit from Israeli training.

Many Israelis remain puzzled by the difficulty in exporting Israeli know-how. Africa is hardly unique in this regard. Former CEO of NaanDan Jain, Avi Hermoni gives one example from India. Hermoni sent a gifted Israeli agronomist, with expertise in apples, to an area near the Indian Himalayas. The agronomist had considerable experience working in the highly successful Bereishit Apple operation in the Golan Heights. He reported back ideal conditions for growing apples: plenty of rain; high altitude that allowed for high day-time and low night-time temperatures; and Perfect soil conditions. Nonetheless, existing orchards were performing poorly. At the time, the apple trees in the Golan Heights were producing 50 to 60 tons of apples per hectare. During his site visit, he found that the India apple orchard yields only reached 1.5 kg. The advisor left a detailed program of what could be done to improve the yields for the apple trees. None of them were particularly expensive and they required little to no additional investment in irrigation systems, pesticides or fertilizers. In the end, however, not a single one of his suggestions was implemented.

Hermoni's conclusion is that Israel can help developing countries – but first there needs to be a real interest amongst the local population and agricultural establishment to adopt new

approaches. He also believes that it makes little sense to send new agrotech technology to developing counties as some sort of a magic-bullet. When Israeli companies have succeeded in helping Africa, it is because they provided a full package of technologies and offered the skill sets required to run them appropriately. Unfortunately, such projects often are associated with the personal economic interests of a political figure, with all the unfortunate implications. The stories are many and generally sound something like this: "A local politician engages Israeli experts and asks for assistance: he provides land with access to a river and says: 'I want to grow tomatoes and cucumbers. You do the rest.'"

Stamina and adequate funding are another factor which are often mentioned. Motti Harari is a seasoned Israeli agricultural expert who has been associated with some seventy development projects in developing countries, especially in Africa. He suggests that it typically takes some five to eight years for a project to become sufficiently profitable and the technology sufficiently integrated into local practices for interventions, oversight and support to be withdrawn. Four years is considered a minimum.

Several experts described failed development projects, that were done entirely "by the book" but then failed, due to inadequate attention to pests. Sometimes simple quarantine measures are sufficient, but often more sophisticated efforts are needed. In one case, an initiative that was well-funded by the Red Cross and managed largely by Israeli experts along with local community members seemed destined for success: wells were dug, net houses constructed, a local agronomist hired and even a reliable market for the produce was available in the form of a nearby 200,000 person refugee camp. But rather than build the nethouses with a double door to keep out pests, the local contractor cut corners and inserted a curtain instead.

The local workers happily opened the curtain each morning to let in sunlight and a breeze– with disastrous results. It took little time for a pest infestation to devastate the project and essentially send it back to square one. Even if a budget for pesticides had been included in the project, it is unlikely that the invasion could have been averted. This is due to the lack of available chemicals, which are only sold hundreds of miles away at the capital, along with the absence of any trained etymologist and pest control experts in the vicinity. What began as a highly promising venture was soon written off as a "total loss". [125]

While chemical companies will always be happy to offer an arsenal of solutions, their interests ultimately remain economic. Hence, it is important to have independent research capacity to introduce IPM practices and evaluate the need for additional chemicals.
In an era of expanding IPM, one of the challenges for biological controls, involves distribution.

There are enormous logistical problems with transporting insects long distances, especially when the final destination may be a remote rural area which has no access to airfields. In an Israeli project in Dubai, natural predators were flown in as cocoons in oxygenated sacks from Guatemala. But the 70-hour, door-to-door travel time proved to be too long even, for the most robust bugs. Eventually, the project began to utilize European insect imports, but even this produced unsatisfactory mortality rates among the natural predators. The consensus is that any African utilization of a biological control program should rely on local insect

production centers that international experts might help establish. Delivering natural predators or sterilized insects to the fields within an acceptable time and with reasonable mortality levels means that biological controls must rely on local facilities. Even though biological controls can lead to a 75-80% reduction in pesticide usage, it is hard to find Israeli experts who are optimistic about the potential of organic crops as an option for Africa, especially in the drylands.

Finally, in order to have a chance at success, it is critical to have a technically proficient, experienced staff member for the project be present on site on a regular basis. One expert describes a site-visit he made to a failed Italian development project in Mozambique. It emerged that the Italian agronomists who oversaw the initiative had never actually visited the site and based all the project specifications on the basis of Italian knowledge and conditions. For the most part, they turned out to be inappropriate.

Some 43% of the land in Africa (13 million km^2) is characterized as drylands.[126] In Israel, the percentage is over 90%. Because such a high percentage of the potential area for farming in Africa is on dry sub-humid, semi-arid or even on arid lands, Israel's general orientation could be helpful in rethinking agricultural strategies for the dryer regions of the continent. For example, for many years it was generally assumed that it is impossible to have a profitable dairy operation in hyper-arid environments. Israel's experience suggests that with an intensive management regime, cows do not need to expend most of the energy in cooling themselves in the sun. A combined program during the warmer months of frequent showers, shading and appropriate feed has made milk productivity in Israel's desert regime comparable to more temperate zones.

At the same time, such measures assume significant supplies of running water and electricity. There is also legitimate criticism about the prevailing notion that cows can be adopted to live in hyper-arid regions. Holstein cows, which have been bred to become champion Israeli milk producers, evolved in Germany's northern most state. While there are undoubtedly ways to reduce their discomfort and maintain reasonable milk production levels, even in the peak of summertime, during the hot months, these cows are not particularly happy animals.

By way of contrast, dates and more recently algae, may provide desert farmers with a relative advantage by virtue of their being grown in hot, arid regions. Long, warm seasons allow for multiple crops to be grown on the same parcel of land, if appropriate irrigation systems can be installed.[127] Hence, an Israeli project in the Ganges Delta increased local farmers' production from one rice crop per year, to three, creating a surplus for hitherto, indigent, subsistence farmers. Revenue leaped from roughly $2,000 to 7,000 / year. Ultimately, an estimated 172,000 Indian farmers came to adopt this strategy.

It is important to emphasize that Israeli agricultural researchers do not limit themselves to studying crops that are endemic to Israel. Many Israeli researchers reveal considerable familiarity with many African crops that are not grown locally. For instance, the NaanDan Jain's Israeli team has had a sugar product line manager on its staff for years, even though Israel does not raise sugar cane. Palm oil is not grown in Israel, but the country has its palm oil experts as well.

The ability to bring Israeli scientific know-how to the qualities of an exotic fruit or vegetable requires interdisciplinary collaboration. Researchers at the Volcani Institute became interested in upgrading guava, even though it has never been an Israeli cash crop due to its high water demands. Nonetheless, an Israeli research team developed seeds for trees that produce a long-lasting fruit. This presumably could improve yields in places like South Africa, where guava orchards are relatively common. In this case, cooperation between geneticist and the post-harvest mavens was natural.

Potential Role of Israeli Training Programs

Israel has acquired considerable experience in the area of agricultural training for African farmers. To date, no serious evaluation study has been undertaken to assess the short or long- term efficacy of these initiatives, although intuitively, everyone (especially the participants) believe them to be terrific experiences. Only recently has Tel Aviv University researcher, Dr. Ram Fishman begun to follow graduates of Israeli agricultural training program to assess the long-term impact of these programs. Clearly, it is high time for a longitudinal follow-up study to see what skill sets are imparted and whether graduates of these programs actually can apply the many ideas that they learn during their stay in Israel – or when attending a local Israeli workshop -- upon returning home. The following are descriptions and qualitative evaluations of Israeli training programs designed to support agriculture in developing countries.

Hebrew University's International Master's Degree in Agriculture

The Hebrew University Faculty of Agriculture offers a one-year international Master's degree. At present, roughly 25 students study in this international program each year. The majority of the participants – some 60% -- come from African countries, primarily representing Ethiopia, Kenya, Ghana, Nigeria and Uganda. Most of these students are single and under the age of 30. Of this cohort, 80% opt to stay for an additional year of residence and complete a thesis. Almost all of these research projects, however, are based in Israel, for logistical reasons. At present the limiting factor for participation in the Hebrew University program is scholarship funding. In other words, for the present, there is no discernible shortage of thesis advisors from among the faculty and class sizes could easily grow without increasing fixed costs.

The goal of the program is to help the students have a deeper understanding of agricultural dynamics and to help students learn how to solve problems. Professor Alon Semach, director of the international program explains that the most basic thing that students learn about in the program is irrigation. Most of Africa has water shortages, and the Israeli technologies in the field offer proven and cost-effective solutions offers a one-year international Master's degree. The majority of the participants – some 60% come from African countries. Of this cohort, 80% opt to stay an additional and complete a thesis. Almost all of the projects are based in Israel, for logistical reasons. At present the limiting factor is scholarship funding, and there is no discernible shortage of thesis advisors from among the faculty. Indeed, many of the researchers from the Government Volcani Institute, serve as adjunct faculty for the graduate program, even serving as thesis advisors.

The goal of the program is to help the students have a deeper understanding of agricultural dynamics and to help students learn how to solve problems. Professor Alon Samach, director of the international program, explains that the most basic thing that students learn about is irrigation. Most of Africa has water shortages, and the Israeli technologies in the field offer proven and cost-effective solutions.[128] Generally, the students come from the same universities, year after year. The Israeli graduate program is far more intensive and demanding than the studies that the African students encountered during their first degree. Given the painstaking selection process and the hard work by the students after arrival in Israel, they are invariably able to cover the required materials.

While the graduate program is a clearly a successful model, it services a relatively small number of individuals. An alternative, more efficient model that reaches a broader audience, might be to have Israeli professors offer special courses in Africa. Most Israeli academic approached and queried about such an option expressed a willingness to offer short courses, if they don't conflict with the regular teaching duties.

The Volcani Institute would like to expand its post-harvest program. Training graduate students from developing countries is one way to do that. But it faces a shortage of funding, especially in the area of scholarships. Because they are not a degree-granting institution, their researchers provide oversight for doctoral and masters fellows in conjunction with the nearby Hebrew University's Faculty of Agriculture. Recently, there is interest in expanding such collaboration to Tel Aviv University. On the whole, there is a great openness to cooperative ventures between Israeli doctoral advisors and academics in African students' home countries.

There is also a consensus among academics who work in the field of agriculture, that a post-doctoral candidate is a better "gamble" than a doctoral student: If a post-doc doesn't work out, she can be sent on her way. And the time commitment is far shorter. Typically, Israeli researchers will travel specially to Africa to interview candidates rather than take a chance on selecting someone inappropriate

Demonstration Farms in Africa

One strategy which is well known in the development literature involves the utilization of demonstration farms or "Centers of Excellence". In the past, especially in India, these centers have been partnerships between Israel and the local governments. Recently, Israel established its first such facility in Africa, a 2.5 million dollar project outside of the Rwandan capital of Kigali, with the aim of "raining and building capacity of farmers and agriculture technicians".[129] The Rwanda Center was established and is entirely run with funds from Israel. With 6 hectares of farm lands, Israeli agricultural techniques involving vegetables in both field and hot-house conditions are raised, with a permanent expert from Israel on staff to oversee and help teach local farmers who participate in training sessions.[130]

Alternative approaches involve partnerships with so-called "early adopters" of technologies. Almost all Israeli agricultural specialists who have worked in Africa have a story about a certain farm, that was successful in growing watermelon or having a pump that connected a village's first drip irrigation system to a local stream. The motivation behind demonstration

farms clearly is national public relations. But if run correctly, they might be an effective vehicle for education and tech transfer.

Mashav Short Courses and CINADCO Internships

Israel's Ministry of Foreign Affairs reports that over the past twenty years, thousands of participants from 140 countries have come to Israel and studied in Mashav run courses. Mashav publishes a catalogue each year with courses of short courses that are offered in a range of topics. Not all involve agriculture, with topics ranging from Science Education to providing children with Emotional Support. This year's menu of courses in agriculture include.

- *Postharvest Physiology, Pathology and Handling of Fresh Commodities;*
- *Intensive Vegetable Production, the Role of Water and Nutrients in Agricultural (For professionals from African States);*
- *Agribusiness, a Tool for the Empowerment of Rural Women;*
- *Irrigation and Fertigation for Intensive Crop Production;*
- *Seed Production and Treatments for Field and Vegetable Crops; and*
- *The 21st Century Challenge: Improving Production of Animal Husbandry.*

Courses in agricultural are overseen by one of the sixteen Mashav affiliated study centers, and frequently administered by CINADCO (The Ministry of Agriculture's "Center for International Agricultural Development Cooperation"), in practice, a joint educational arm of the foreign and agricultural ministries. Experts from the Volcani Institute or Hebrew University frequently take responsibility for agricultural course content. While most courses are taught in English, there are instances where students learn in French or other languages, such as French, Spanish, Russian and Arabic. The 25 courses offered to some 500 during any given year are intensive, typically running for 2 to 4 weeks at the Beit Dagan center or in the CINADCO educational facilities at Kibbutz Shefayim, north of Tel Aviv. Generally, the Israeli hosts cover the participants' expenses.[131]

Every year since 1999, Volcani Institute Professor Elli Fallik oversees a such course sponsored by Mashav and the Ministry of Foreign Affairs for international participants on Post Harvest practices and technologies. Invariably it is attended by a large cohort of Africans. Fallik, and the classes he teaches, are quite popular. Frequently graduates return home and initiate local courses that Fallik and his colleagues are invited to fly in and run.

Yaakov Peleg, the director of CINADCO describes the goal of the agency training programs as "passing over knowledge and capacity building". The courses are tailor made to the circumstances and interests of the visiting groups. While he is proud of the professional training, he believes that the most meaningful educational experience takes place in CINADCO's 11-month agricultural internship program, where 4,000 young, aspiring participants are hosted each year by Israeli farmers around six training centers. The farmers are selected based on their particular expertise or for their reputations as entrepreneurial leaders and "trail blazers". The students not only learn about modern Israeli agriculture, but get to see how Israeli farmers "think" over the course of a year. The farmer/mentor explains their day-to-day decisions: "why he decided to pick the fruit at a given time?"; "why she selected a given pest control strategy?"; "why he have chosen the crops that they did?" etc.[132]

It is also worth noting that the thousands of young people who are selected for CINADCO courses are a rarefied group. Minister of Agriculture Director General, Shlomo Ben-Eliyahu describes them as a local elite that come from families that can afford to send them to universities and who have stature within their communities. Then there is the self-selective qualities of individuals who choose to fly across the world, work in farms in order to learn entrepreneurial skills.[133] It should not be surprising that these training programs in Israel manage to catalyze an impressive array of agricultural, entrepreneurial activity in developing countries and communities.

Having seen the amazing transition in his program's interns from Africa and South-East Asia, Peleg argues that the problem of developing agriculture is not access to a given technology, irrigation, etc. per se. Rather the reason why new agricultural initiatives are not successful comes down to awareness and even mentality. He believes that by the time the CINADCO students go home, they have changed. They return as entrepreneurs and start new projects with much higher success rates than typical aid recipients. Roughly 120 new ventures are established every year by graduates who return home. While many do not succeed, as much as a third do.[134]

The Arava International Center for Agricultural Training

The Arava International Center for Agricultural Training (AICAT) is perhaps the most innovative example of Israeli agricultural training for Africans in the country.[135] Every year 1200 participants come for a 10-month program to the Central Arava, a fairly remote agricultural region, in one of Israel's southern deserts. There they work in local farms five days a week and hear lectures about dryland farming techniques one day a week. It is essentially a work-study program. Participants cover the entire costs of their travel and study by gaining experience and joining the work staff of area farms.

The student body of the program is fairly diverse in its national origins. Roughly half the students are from a range of East-Asia lands while half are from Africa. For example, Indonesia, an Islamic country without diplomatic relations with Israel, sends a large group of students each year. In the past most of the African students were from Ethiopia, although in recent years, the proportion of Kenyans has also increased. Many are currently students in university programs which grant these students a year of college credit for their participation. Recently, in conjunction with Tel Aviv University's Food Security program, outstanding students in the AICAT program can continue their studies in Israel for a Masters' degree.

Recruiting to the program is facilitated by Mashav and Foreign Ministry's staffers who come to Africa annually to interview candidates. Typically, participating students' English is considered to be very good and most of the African participants are described as "middle-class" and not belonging to the rural poor. Demand to participate in the program is purportedly strong and African participants' motivation is described as particularly high. Last year, some 50 students returned to Africa and opened up small business, many having to do with agricultural ventures.

Netta Robbins, a lecturer in the program for six years, says that there is special interest among the African students to learn about irrigation as well as agronomy and the business aspects of farming. This includes topics like marketing surveys, European certification requirements, etc. Many of the ideas for their new African entrepreneurial business ventures are hatched while studying in consultation with their teachers. In the past, they have addressed fundamental problems such as lack of access to reasonable quality water as well as transportation of produce and delivery of food to markets.

Robbins describes the program's primary educational challenge as "getting students to 'open their minds' to new ideas and get beyond the notion that *'my father farms this way or my neighbor farms this way, so guess I will too.'"* The crops that receive the greatest emphasis in classes are the ones that are found in Africa's local markets: potatoes, onions and tomatoes. The academic staff seeks to get students to consider economic models and simple related challenges. For instance, "How can I change my tomatoes to ripen two months earlier so I can get a better price?"

Training Programs Outside Israel

CITNADCO also supports around 25 courses around the world, which reach 500 to 600 local farmers. Two Israeli experts typically travel to give a course that lasts 2 weeks on a particular topic. These usually convene these at a local college, also times they take place in the field. Accordingly, five or six times a year, Volcani research Elli Fallik leaves his laboratory and travels around the world, mostly to developing countries, to spread the gospel of extended shelf-life and reducing the extraordinary loss of food due to poor practices and ignorance. Because he is a researcher at a government-run institute, technically Fallik is a civil servant and cannot receive pay for this work. But he believes that spreading the gospel of food storage and safety contributes to world food security.

When he travels to teach, insists that his classes include farmers and are not just attended by academics. Fallik's approach highlights one of the main reasons why Israeli agricultural innovations have been so successful locally. It is extremely unusual in developed -- and especially in developing countries, for academic experts in agronomy to go into the field and meet with farmers. Subsistence smallholders are simply not considered worth meeting with. Recently, the American aid agency U.S. AID invited a team of Israeli scientists to come to the country of Georgia to run an educational program. Naturally, the Israelis asked: "Why aren't you inviting Americans? It's not like there is any shortage of U.S. experts." The American government officials' response was surprising: "Our scientists don't know how to work with small farmers."

Another reason why Israeli training programs are supported by foreign governments is because they are inexpensive. Israeli government scientists, among the world's best – are available "on the cheap". As mentioned, public servants are not even allowed to supplement their government salaries. As a result, total expenses to pay for a team to teach a course in post-harvest practices can cost as little as 1500 dollars/day to cover the entire teaching staff's expenses.

The Israeli Foreign Ministry would also like to increase the dissemination of Israeli know-how about post-harvest activities in Africa. The problem until now has been: "who will pay

for it?" The UN Food and Agriculture Organization (FAO) is loath to support Israeli post-harvest initiatives due to the political sensitivity surrounding Israeli participation. Sometimes, such involvement is supported indirectly, through grants to third parties. On other occasions, European or American aid agencies have made grants directly to the Volcani team

As mentioned, a special report was prepared by the agricultural team at Tel Aviv-based NGO, *Start-Up Central* highlighting the benefits of Israeli agrotech innovation for Indian agriculture[136] A brief summary of some of the findings of the survey is instructive ,not only for understanding the breadth and potential that Indian/Israeli cooperation in agrotech could spawn. The findings are also highly relevant in the Chinese context as well. It is also well to note that unlike agrotech products and services designed for African smallholders, which often have some philanthropic component, Israel's orientation towards India is entirely commercial, given the country's burgeoning economic capacity.

Hybrid Seeds

Due to their superior performance, Indian farmers already spend some 4 billion dollars each year on hybrid seeds and the demand increases annually by roughly 15%. Over the years, Israeli seeds have proven to be critical in dryland agriculture where salt and drought resistant seeds are essential for economically viable and sustainable crops. In some cases, rather than seed varieties, Israeli scientists develop new commercial plants with commercial potential. For example, the Indian firm *Pioneer Aromatics and Agri Solution* purchased five varies of medicinal plants for three million dollars (from three growers) in farms in the Arava desert. The herbs are deemed to be aromatic substitutes to peppers and contain properties which the Indian believes makes them an alternative to Viagra.[137]

Among the Israeli companies with the potential to meaningfully contribute to Indian identified in the Wikistrat/Start-Up Nation Central report are:

- *Agreen Seeds;*
- *OriGene Seeds;*
- *Top Seeds;*
- *NRGenes;*
- *Hazera;*
- *Kaiima; and*
- *Evogene.*

Biopesticides

Toxic chemicals utilized for pest control in India are increasingly implicated in the acute poisoning and deaths of local farmers.[138] With inappropriate chemical pesticide applications affecting public health negatively and contributing to pest resistance, biopesticides are a critical component to plant protection strategies. But 140 biopesticide production units presently operational in India are only able to supply about 1% of the cultivated lands in India. Effective, environmentally-friendly control solutions have not yet been found for many pernicious, local agricultural pests. Among the leading Israeli companies, developing biopesticides singled out for their potential contribution to reducing pest damage to Indian crops are:

- *BioBee;*
- *Timorex Gold;*
- *Botanocap;*
- *BioFeed;*
- *Agro Shelef; and*
- *Tamar Tech.*

Comprehensive Irrigation, Fertigation and Chemigation Solutions

India is home to about a fifth of the people on the planet, but only one twenty-fifth of water resources worldwide. Low-efficiency and poorly managed irrigation systems have depleted ground water resources in many areas of the country with water constituting a bottleneck for improved yields and prosperity. Although, ostensibly, government policies have come to recognize the relative advantages of drip irrigation systems, only 10% of cultivated lands that should utilize drip irrigation systems actually do.

There are several Indian companies that have begun to meet what should be an enormous demand for micro-irrigation systems, but they probably lack the quality and experience of Israeli companies and they do not offer the full chemigation/fertigation applications that have been deployed so successfully by Israeli companies. This may explain why the Jain corporation decided to purchase Na'an irrigation systems some ten years ago and has gone on to dominate Indian micro-irrigation sales, with a reported 55% market share. Nonetheless, there are several Israeli agrotech companies which are posed to make a contribution to improved irrigation in India. Besides *Na'an Jain*, *Netafim, Rivulis* and *Metzerplas* are already active in India with prospects for start-up companies like I-*dripper, Tevatronic, Amiad, Inplant* and *Tal-Ya* encouraging.

Farm Machinery

The vast majority of Indian farmers do not utilize the full array of the latest farm machinery with its proven ability to dramatically reduce labor and expand the scale of farms and farmer performance. For example, land levelers, blade harrows, inter-row cultivators, vacuum and mechanical planters, along with a variety of planting implements could revolutionize many Indian farm operations. This is especially true for smallholders, who typically utilize extremely old and inefficient mechanical farm equipment. The report estimates that over the coming years, demand for modern farm machinery will expand at an annual rate of 8%.

While Israel is probably less of a "powerhouse" in the area of farm machinery than in other areas, such as irrigation systems, there are new Israeli star-up companies identified in the report who could improve different aspects of agricultural mechanization. Accordingly:

- *Etgar and Yung-Etgar;*
- *Hishtil*;
- *Virentes*, -- and its grafting technologies; and
- *Syx* along with several other companies that outfit drones with autonomous spraying and monitoring capabilities.

Advice and Knowledge Sharing

While India has established itself as a significant player in software design and other hi-tech sectors, it is surprising to learn that rural India remains largely unaffected by the tech revolution. For instance, roughly 90% of Indian farmers still do not have internet access and only a fifth of this cohort owns smartphones. As broad band access begins to expand across the sub-continent, the potential to provide valuable agronomic information, market conditions and weather reports in real time to Indian farmers will also grow. Among the Israeli company's considered appropriate to help in the critical task of information dissemination to farmers are

- *Cultivu;*
- *Agriculture Knowledge on-line (AKOL);* and
- *AgriTask*.

Other Israeli companies like *Farmster*, that presently focus on Africa, could easily make a geographic transition to India.

Resource Management and Precision Agriculture

To improve fertilizer and irrigation water usage, decision support systems and information / communication can let farmers know actual soil humidity levels and other diagnostics, plant conditions along with pest recognition and other alerts in real time. This information is critical for optimal resource utilization and a transition to so-called "precision agriculture". The new, information-driven systems can offer enormous savings for farmers by reducing inputs which frequently have a negative impact on the environment. The report notes that this is an area where Indian farmers have not kept up with advanced practices and where Israeli information and decision support systems could make a significant contribution. Among the relevant start-up Israeli companies that have the potential to help are:

- *Sol Chip*, and its solar energy sensor;
- *CropX, Manna Irrigation,* and *Saturas*, designed to support "smart irrigation:,
- *Taranis* and *ATP labs* that offer farm monitoring services; and
- *Farmdog* and *FieldIn* have systems which expedite effective integrated pest management.

Post-Harvest and Integrated Value Chains

Internal Indian estimates suggest that the value of agriculture crops lost at the post-harvest phase reaches as high as 13 billion dollars. This is a particularly prodigious sum when one considers the modest income of the smallholders who only receive a fraction of the economic benefits from their produce. Food loss at the farmer level in India can be attributed to a range of factors so there is no "magic bullet" that can be called on in reduction strategies. The loss might due to pest infestation (birds, insects, rodents, fungi); to lack of refrigeration; or unreliable supply chains and transport systems. The good news is that cost-effective technologies are available: special storage bags, ethylene removing packaging and edible coating to mobile cooling units for short transport and modified atmosphere packaging, to name a few. Many Israeli companies offer products which address these problems. The report singles out:

- *Amaizz* and *Pimi Agro*, for storage products;

- *BT9*, that has “cold chain management”;
- *Aclartech* that analyzes fruit ripeness;
- *Yarok*, and its food safety testing system and
- *Stepac* and *R.O.P* that provide modified atmosphere and humidity packaging.

Part VI: Israeli Agrotech: Practical Options for Smallholders

This section offers a review of several promising innovations in agricultural technology developed in Israel which may be particularly germane for smallholders in Africa, China and India, along with ideas for introducing them to this vast cohort of farmers. The many researchers and entrepreneurs interviewed were delighted to present the agricultural and economic benefits of adopting their particular innovation in the context of African smallholders. Nonetheless, almost all emphasize two points:

1. In assisting smallholders, it especially important to think of providing an entire package of assistance to farmers. Irrigation, productive seeds or plant protection are very important. But if introduced as stand-alone initiatives, they are unlikely to produce the desired improvement in yields and smallholder prosperity.

2. Economic feasibility requires minimal economies of scale for companies interested in introducing modern agricultural techniques to remote, often poverty-stricken communities.

As described previously, in order to make it worthwhile for businesses to engage smallholders, that must organize into larger frameworks (cooperatives, farmer unions, etc.). The distances and times involved in engaging rural African smallholders will be excessive to produce a positive cost-benefit ratio.

Reports about the following areas of agriculture and technologies being developed in Israel, with an eye towards dissemination among African smallholders, are presented according to the following topics:

1) Irrigation and Water Management;
2) Integrated Pest Management;
3) Animal Husbandry and Dairy Science;
4) Post-Harvest Food Protection, Storage and Food Safety
5) Knowledge and Market Information Dissemination

1) Irrigation and Water Management

The Sociological Origins of Israel's Irrigation Industry

Israel's remarkable irrigation industry can be explained as a pragmatic response by Israeli farmers on several Kibbutzim who faced a range of practical problems.[139] Israel's largest two irrigation companies "Netafim" and "NaanDan Jain" were established on these communal farms. Plastro, established in 1966 by Kibbutz Gvat, in the Jezreel Valley is the third Israeli irrigation super power.

Because practically none of the original kibbutz members had grown up in farming communities, they did not bring with them preconceived notions. At the same time, many

were raised with strong technical and scientific educations. Although ideologically, they were committed to agrarian lifestyles, the challenge of creating competitive agricultural operations in dryland regions pushed them to seek innovative solutions. Through trial and error processes, they eventually came to create companies that today control over half of the global drip irrigation market.

Other kibbutzim created industries related to water management and irrigation: Kibbutz Amiad manufactures water filtration systems; Kibbutz Evron established Bermad which specializes in manufacturing hydraulic control valves for irrigation and other non-agricultural applications. Kibbutz Ma'agan Michael's Plason factory makes plastic fittings and spigots for water systems. Kibbutz Hevtzibah specializes in production and repairs of water meters. Other kibbutzim, like Eilon and Beit HaShita make heavier agricultural equipment while Kibbutz Sdeh Eliyahu, created factories to produce insects for local IPM efforts and for export.

All of these farming communities were responding to insights gained by members who were dealing with real world agricultural challenges. For example, rural legend has it that farmers at Israel's northern border settlement, Kibbutz Evron, were concerned about their personal security and the risk of going into the fields in the dark, early morning hours to open the valves for the irrigation, due to exposure to potential snipers or terrorists just over the border. This led to their invention of the automatic water valve. The associated water savings turned out to be a bonus.

It is possible to distinguish between two types of initiatives involving R&D for irrigation. One group utilizing irrigation infrastructure to optimize agricultural inputs (e.g., fertilizers and of course water itself.) The other involves designing new technologies which can deliver water even more efficiently and less expensively to plants and trees. The Gilat Soil and Water Center, the southern campus of the Volcani Institute, has an impressive team of experts working on a range of problems associated with desert agriculture. It is particularly eminent in the area of water and irrigation. Not only is their publication record extraordinary, but its scientific team is also solving many fundamental agronomic problems. Indeed, irrigation and fertilization regimes around the world have probably changed due to the findings generated at this somewhat remote research station by its staff of less than forty researchers and assistants.

For instance, recent experiments at Gilat assess the effects of different fertigation on trees. While there is a plethora of studies about the optimal timing and levels of fertilizers for vegetables, there is a surprising paucity of empirical field trials involving fruit trees. That's probably because it takes considerable time for trees to mature and researchers need to produce publishable papers for promotion according to a much tighter schedule. After completing field trials in the area of optimal fertilizer regimes for olive trees,[140] three major experiments are presently under way focusing on irrigation and fertilizer regimes for almonds, avocadoes and pomegranates. Among the insights gained already is that when the optimal level of nitrogen is exceeded, the quality of olive oil decreases and the trees yield less fruit. Excessive fertilization of other fruit trees can lead to greater numbers of male flowers and less of the females that actually produce fruit.

Almond Tree Fertigation Experiment, Gilat Research Center

The Netafim Empire

The *Netafim* corporation is synonymous with the invention and development of drip irrigation. The company is arguably the "jewel in the crown" of the exceptional agricultural innovations that emerged from Israel's "kibbutzim", the Israel's diverse network of 270 intentional, Socialist communities. In fact, the actual invention of drip irrigation is attributed to Simcha Blass, the brilliant and irascible first Director of Water Resources for the nascent State of Israel.[141] In his autobiography: *Water in Strife and Action* Blass describes his "Eureka moment" while visiting a friend at the rural town of Karkur in the 1930s. Blass noticed the exceptional growth of a tree that was watered by a leaky pipe that left droplets of water on the seemingly dry soil surrounding the tree. He writes: "*water droplets raising a giant tree hit me like a mosquito in the mind of Titus the evil."*[142]

Blass would only have the time to develop the idea when he retired from public service. Fortuitously, the end of the 1950s also heralded in the advent of low-cost plastics. In his revolutionary system, water is delivered to trees and plants through narrow, black plastic piping system and released, "drop-by-drop," above the root zones through cleverly designed drippers. Tests showed that the slow release of water produced yields far higher than comparable sites using flood or furrow irrigation. The amount of water required was a fraction of that utilized for the conventionally irrigated crops. Drip irrigation also solved a range of technical problems, allowing for irrigation on steep terrains on shallow soils, both sandy and with clay.[143].

It would take some time for Blass to find the correct partners for his new venture. Eventually, he brought his invention to Kibbutz Hatzerim, a struggling communal farm in Israel's arid southlands. It served for many years as headquarters for the new *Netafim* company, established in August 1965 and is the site of one of the company's largest factories. The farmers proved to be highly resourceful and the new factory not only created a highly efficient production system, but established an R and D department that continues to upgrade the efficiency and, integrate fertilizer applications. Subsequently, the systems were automated and operated by computers. Later new "subsurface" systems were

designed that reduced water evaporation and associated losses. When production began to exceed the capacity of the kibbutz, two other kibbutzim Magal and Yiftah were brought on board, even as Hatzerim retained 55% of the company's stock. Eventually, external investors were recruited to provide capital, and the company grew rapidly. But this forced the Hatzerim founders to dilute its stock holdings and it didn't take long for the other two kibbutz partners to sell their shares to international corporations who quickly acquired controlling interests

Recently, *MexChem* purchased some 80% of *Netafim* stock for a reported price of 1.9 billion dollars.[144] The new owners made a strategic decision to maintain *Netafim's* historic character as an Israeli based company: Kibbutz Hatzerim retains 20% of its stock ownership. According to the sales contract, signed on February 2018, the Israeli management will continue to run the company. Corporate headquarters, along with the present factory production, will remain in Israel. Kibbutz Hatzerim also retains two seats on the international corporate board. The company is set to grow and further dominate the global drip irrigation market. But does it have any answers for the irrigation challenges and modest budgets of smallholders?

Family Drip Systems

There seems to be evidence that a few companies played with the idea of creating a drip irrigation system that would not require electricity and pumps and that could be adopted smallholders. But it was *Netafim* that created a product which it hoped would sell throughout the developing world: *Family Drip System (FDS)*. The primary advantage of FDS is that it requires no centrally-pressured water system. Rather it runs on a gravity-based flow which allows farmers to farm in remote areas, without the benefit of pumps and electricity and still have access to low-volume drip irrigation technology. Typically, a tank, is raised to a height of some 1.5 meters, filled with water and then the water is released into the heavy-duty, polyethylene pipes, with drip outlets spaced at 30 cm. intervals. Kits come in a variety of sizes, accommodating plots ranging from 100 to 2000 m^2. A 250 square meter kit can cost as little as 150 dollars. Figure 4 offers a photograph of an operational family drip system in India.

Family Drip System in Indian Community Irrigation Project

Irrigation with family drip systems has been shown to be particularly effective when soils are at one of the extremes: either heavy in clay or sandy. The importance of the family drip system is the minimal maintenance required to keep the system in operation: farmers only need to make sure to clean the filter prior to usage. The steady drop in the height of the water tank became possible over time, with the reduction of friction (surface tension) in the new designs.

It is worth noting that the motivation for developing the *Netafim* Family drip system was not philanthropic. Rather it reflected a recognition that *Netafim* would do well to offer a product to the 500-million-person market of smallholders, worldwide, who produce 80 percent of the developing world's food.[145] Unfortunately, years later, in retrospect, it seems that the product never really taken off.

There are several reasons for this. For most subsistence farmers, it remains a prohibitively expensive product. It also soon became apparent, that the small radius of the basic family drip system was inadequate for anything but the tiniest of farm units. *Netafim* realized that it needed to increase the range of the product. But the name, however, had already attained a certain level of recognition and traction in the developing world. So *Netafim* decided to offer a new line of larger systems, available as irrigation *NetKits*, that contain small to medium sized irrigation systems. *NetKit* systems can deliver water to parcels as large as a hectare --- a cultivated area which is beyond the scale of a typical subsistence smallholder. Regardless of the actual size in the series, all *Netkits* share similar specifications: The same dripper wall thickness; the same size pipes, drippers, platforms, etc.[146] Yet their capacities are entirely different.

By way of example, recently Netafim's Africa sales team sold 110, one hectare NetKits in Malawi. In terms of cultivated lands, this is comparable to a few thousand 250 m^2 *FDS* networks. Generally, NGOs working with small farmers find the one-half hectare *Netkit* system to be optimal for supporting a farmer's transition from a subsistence to a commercial operation. The impression of *Netafim's* Africa staff is that the classic *FDS* system, which requires the manual lifting copious amounts of water to the tank every day, is not sustainable over the long run. For most of these small farmers, it's just too much work. The alternative is to install low cost pumps. Yet, none of the available pumps which might be used are particularly well-suited for the task. Solar-powered pumps have great promise, but still are too expensive for most smallholders. Best estimates suggest that a solar-powered pump will absorb as much of 75% of the costs of an *FDS* or *Netkit* irrigation system.

Naty Barak, a member of Kibbutz Hatzerim and veteran Netafim manager, serves as the corporation's chief sustainability officer. Barak is convinced that an expanded presence in Africa should be a strategic target for the company: The continent is the only place left in the world where significant land and water reserves exist for enlarging agriculture. Moreover, demographic trends suggest that food production will have to expand in Africa dramatically if the population is to have even minimal food security. While he personally believes that the company should more energetically promote the promotion of family drip system in Africa, past CEOs saw India as a more promising market.

Netafim's corporate management has traditionally been disinclined to prioritize sales of individual units for a few hundred dollars for smallholder operations, given the task of servicing dispersed users in Africa. The logistical complications are daunting and the potential profits limited. Rather it prefers to wait until opportunities appeared for creation of a "critical mass" of users (say at the village level). At a minimum, the company would hope to be able to serve 5-10 units in a community that used drip systems. The upshot of these dynamics is that while *Netafim's* annual sales in Africa come to roughly 70 – 80 million dollars, roughly 1% is involves purchases by and for smallholders.[147] Those acquiring family drip systems typically do so as part of a philanthropic intervention by U.S. Aid, the Rockefeller, Gates or Syngenta Foundation. Occasionally, drip systems are acquired through financing of a local Development Finance Institutions (DFI).

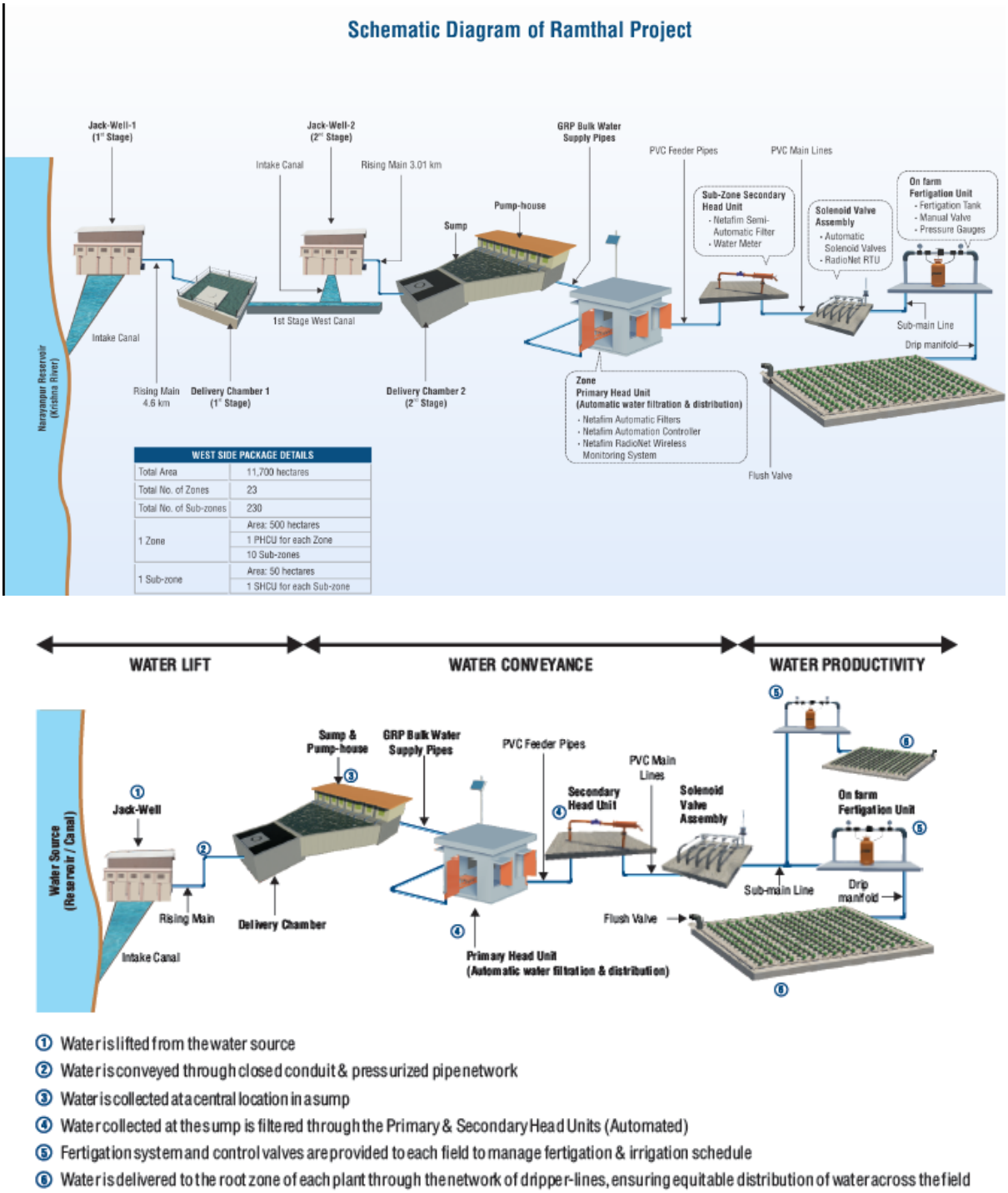
Part of the problem involves political stability. Tal Argaman, based at *Netafim's* facility at Kibbutz Magal oversees the family drip line for Netafim. He explains that there is a fundamental difference between ventures in India versus Africa. One can simply not expect continuous support or even steady governance for the eight to ten years that it truly takes to make the kind of economic transformation that is required to fund a drip irrigation infrastructure. In India, this kind of long-term commitment is an operating assumption. Not only governments are capricious. Indeed, U.S. AID is considered unreliable, hampered by all sorts of political vicissitudes and an inability to make long term commitments.

In an effort to surmount past limitations, *Netafim* has begun to back away from strategizing about Africa *as an entire continent unit* for reaching out to smallholders. Rather it prefers to focus on a single country that offers some objective basis for overcoming the profound obstacles to reaching an African market. Kenya and Ghana are natural candidates for prioritization, as both have reasonable infrastructure, relatively strong English language literacy and supportive governments. Sales are also relatively strong in Tanzania and Ethiopia as well. "To start a smallholder program in a country Burundi, where there is nothing in place at all to help support an irrigation program -- no roads or cars -- to begin with, to me seems like a less than judicious strategy. "

Barak explains that it is no surprise that demonstration projects in Africa initiated by sundry philanthropic or non-profit initiatives showing drip irrigation systems' potential have not gone "viral" and transformed local thinking about irrigation strategies. "The story of the *Millennium Villages* makes for a great photograph but is not sustainable." he explains. Only when a farmer understands that it will truly help his business to move to drip irrigation will progress be seen. That's why he strongly advocates the *Community Micro Irrigation* model, recently applied by *Netafim* in Karnataka India – that serves a s a proof of concept of sorts.[148]

Karnataka, the seventh largest Indian state (191,000 square kilometers) with over 60 million people, provides an example of how a community irrigation project in a poor region might work and how drip irrigation could be disseminated among smallholders. *Netafim* launched its largest project in Asia at Ramthal Karnataka. The project involves 11,700 hectares of farmland and some 6,700 small farmers, with average land holdings of 1.74 hectares (with farms ranging from 0.4 to 10 hectares)

Technically the project succeeded because not only did it enjoy political stability, it was based on a significant infrastructure: a network of pressurized pipelines rather than canals or other distribution channels. Figure 5 offers a schematic demonstration of the design.



① Water is lifted from the water source
② Water is conveyed through closed conduit & pressurized pipe network
③ Water is collected at a central location in a sump
④ Water collected at the sump is filtered through the Primary & Secondary Head Units (Automated)
⑤ Fertigation system and control valves are provided to each field to manage fertigation & irrigation schedule
⑥ Water is delivered to the root zone of each plant through the network of dripper-lines, ensuring equitable distribution of water across the field

Figure 5: Design of the community drip program in Kanatka India

From *Netafim's* internal publications, agronomically the results were dramatic. On average, yields for tomato, chilly, cabbage, capsicum, potatoes, ginger, karela and kheera either

doubled or more than doubled during the first harvest after installation. These figures have not yet been confirmed, however, by independent evaluation research. Table 1 shows the associated economic calculus for individual farmers:

Table 1: Summary of Netafim Smallholder Initiative in Jharkhand, India

Annual Crop Plan Cost	Tomato Crop 1 July-November	Cabbage Crop 2 November- January	Bittergour February to June
Drip Costs	**$400**	**0**	**0**
Pump	**475**	**0**	**0**
Inputs	**$100**	**$100**	**$100**
Plant Costs	**$45**	**$45**	**$80**
Labor	**$50**	**$50**	**$50**
Total Costs	**$670**	**419**	**$230**
Yields/Production	**2320 kg@$0.42**	**9000 kg@$0.8**	**2500 kg@$0.30**
Sales	**$970**	**$720**	**$750**
Gross Profit	**$300**	**$525**	**$520**
Bank Payments	**$250**	**$525**	**$520**
Net Profit	**$50**		
Pay Back Period	**5 Months**		
Benefit/Cost Ratio	**2.23**		
Net Benefit	**$1095**		

Source: Netafim 2015

The purported success of the Karnataka project was due to institutional rather than engineering breakthroughs. It was essentially a public-private partnership, proving that in drip irrigation dissemination, public policy matters. Barak explains that the state government did all the "right things": it engaged some 23 Water User's Association that took on the task of initial publicity and farmer training. The Associations went on to form 230 Water User Groups, which were a critical organizational framework for implementing the 5-year maintenance guarantee. It also found the money to make a significant investment in the new irrigation infrastructure. A fund was created, based on local government financing, bank loans and support from *Netafim* itself.

The price of family drip system depends on the region where it is sold. In this case, the kit cost 500 dollars: Smallholders received half this sum (250 dollars) as a direct subsidy / grant from the state government as an investment in the "low-tech" new drip irrigation infrastructure. The other 250 dollars were financed for the farmers, by UNDP and the Bank of India, offering an accessible credit base. And there was also competition. Many of the drip systems were provided by competing irrigation companies.

The assumption was that it would take some 50 months for farmers to recoup the initial investment. In fact, drip systems allowed farmers to grow three crops during a calendar year rather than one. As a result, most farmers returned the government loans within twelve months – or one to two growing seasons.[149] To scale up this "calculus", it is critical to ensure

reliable markets for the expanded crops and yields. This can come in the form of an agreement with a reliable, major buyer. For instance, a long term contract with a “Nestles” or potatoes for supply to *Frito-Lay* can change the investment time horizon completely. *Netafim* reports that its usual irrigation efficiency levels (80-90% water and fertilizer use efficiency) were achieved, allowing for the area of cultivated land to be dramatically expanded with no significant additional demands on water resources.

Within a year, the Indian “smallholders” had moved on, independently growing cash crops like tomatoes, with their drip irrigation systems. Barak believes that the solid corporate revenues are not the real story of what happened in Karnataka. Rather, in retrospect, he sees the venture as a textbook example of capacity building. The technology allows for tens of thousands of poor people to happily transform their identity from subsistence farmers to agricultural entrepreneurs.

A similar program, on a far smaller scale, was run in Kitui, located in the in the semi-arid Nzambani District in eastern Kenya. Working with a group of 200 farmers – primarily HIV positive women who were simply unable to continue bucket irrigation -- family drip systems were installed with the help of the local primary school. But the project lacked the institutional backing of a regional government, which made the Indian initiative such a success.

Netafim family drip systems meet conventional irrigation in Kitui, Kenya.

Netafim managers who are more familiar with the reality in Africa are quick to point out some major differences between the dynamics in India and what can be expected in Africa: In India, it was the state government who was the initiator and who brought the entrepreneurial spirit to the project. In Africa, the impetus will need to come from

philanthropic or nongovernment quarters. The *Netafim* Africa team admires the myriad NGOs who heroically try to step into the present vacuum and contribute as best they can. But the overall impact after many years and demonstration projects appears to be modest and unlikely to scale up any time in the foreseeable future. *Netafim* managers are not sure that the Karnataka community model can be applied to African smallholders without a patient and powerful philanthropic partner.

Part of the problem is a fundamental paradox that exists when disseminating new agricultural technologies among African smallholders: Because the new users live in relatively remote locations and don't have access to spare parts or the ability to fix broken systems, technologies need to be resilient. But at the same time, if you design a product to maximize resilience, it quickly becomes too expensive for the farmers' extremely limited budgets. At the same time, independent agricultural experts explain that this dynamic is critical to understanding the remarkable success of Netafim in places like Thailand. There locals describe their allegiance to *Netafim* drip systems, which may have been expensive to purchase, but are still working fine after fifteen years.

Past interactions between *Netafim* with *IDE* (the International Development Enterprises) is telling about the company's perspective on this issue and on irrigation in Africa in general. *IDE* is a private aid organization that purportedly works with a staff of 1000 fully and partially paid employees in 14 developing countries in Asia, Africa and South America. Its activities are diverse, ranging from sanitation to hygiene. The organization seeks to utilize markets as the "most powerful force for significant, widespread and lasting impact on rural prosperity." In other words, it sees smallholders as potential business partners. The organization's website: www.ideglobal.org, promises donors that for every dollar that they send to IDE, the organization will turn it into at least $10 of income for a family living in poverty." (Here again, no independent, peer reviewed evaluation research is cited.)

Paul Polak, the organization's Denver-based founder (and now board member emeritus) approached *Netafim* in the 1990s with a request that it produce an inexpensive, small drip system for his organization that *IDE* could disseminate throughout poor areas of the world. Polak specifically asked for a lower quality, cheap, drip system so that he could reach more farmers. Netafim was not inclined to "prostitute its product" to help Polak promote his vision. The company takes pride in the fact that the high quality of its drippers is exactly the same for simple family systems as it is for complex, computer run irrigation networks. ("The plant doesn't know that there isn't a 20,000 dollar system behind the drop of water it receives.")

Polak moved on and quickly found other more flexible producers, receiving multi-million dollar grants, largely from the Gates foundation, to generate demand for its drip irrigation project. His Wikipedia page claims that in retrospect, *IDE* has ended poverty for 19 million of the world's poorest people, by making radically affordable irrigation technology available to farmers through local small-scale entrepreneurs.

But *Netafim's* perspective has a very different -- and less favorable – perspective on IDE's work. As they see it, the venture caused enormous damage to the image of drip irrigation throughout developing countries and harmed the future willingness of smallholders to

adopt efficient irrigation technology. The family drip systems that IDE disseminated were of particularly poor quality and the drippers were quickly and constantly getting clogged. When a *Netafim* representative asked how *IDE* helped farmers overcome these technical problems, Polak explained that users received a safety pin with the systems which could help pick out particles that clog the system. *Netafim* representatives describe jabbing a safety pin into such an intricately designed irrigation dripper as tantamount to bringing a "graven image into the Holy temple."

The alternative *Netafim* strategy focuses on longevity and reliability. Its systems still remain fully functional after twenty years. Due to their inimitable dripper designs, clogging is not a serious problem. Looking ahead, Netafim doesn't envision its family drip design changing very much as it believes that the product is extremely well-planned and works quite well. Yet, it does believe that as solar electricity begins to be more common, and remote villages begin to have access to even a modest electricity supply, smallholders may be able to scale up to conventional drip systems far more expeditiously than in the past. The company believes that even smallholders need to become more professional farmers, enabling them to enjoy the benefits of modern, precision farming.

Research has confirmed the high percentage of defunct drip irrigation systems throughout Africa which are quickly abandoned or transformed into hammocks and other non-irrigation functions. The reasons for the poor performance are many. They include poor water quality, water storage problems and damage by destructive wildlife.[150]

Drip Competitors

Unlike Kibbutz Hatzerim that was established at a remote, desert outpost, Kibbutz Na'an was established sixteen years earlier, in 1946, in the center of Israel. Perhaps because of its convenient location, today it is the most populated of the country's kibbutzim. The community's entre into irrigation evolved from a workshop designed to support Na'an's farmers into a major factory. But the 1970s Kibbutz Na'an was producing a range of irrigation equipment, beginning with sprinklers, and eventually adding drip and micro irrigation systems. In 1970, Na'an merged with a company specializing in small sprinklers operating out of Kibbutz Dan in the northern Galilee. It later purchased the Dan factory outright creating *NaanDa*n. The company operated independently for over thirty years until it was sold in two phases to *Jain* Irrigation, India's largest irrigation company, for 60 million dollars: 50% in 2007 and the remaining shares in 2012. [151] Although *Jain* has some 10,000 employees in installations world-wide, the sales agreement agreed that production at the Na'an plant would continue unchanged. Eventually, an Indian CEO was brought over to Israel in 2015 to oversee Israeli operations. But true to its promise, *Jain* invested heavily in expanding NaanDan Jain's Israeli manufacturing capacity.

Avner Hermoni, a former officer in Israel's Paratrooper Battalion, was chief executive officer at NaanDan when it was sold to Jain and went on to serve as the CEO of the new NaanDan Jain company for seven years. He believes that the deal made sense for all sides: It catapulted *NaanDan's* global stature and reach to new levels, while giving the Indian partners access to Israel's unique experience and knowledge – "even if they are not always inclined to take the Israeli advice". *Jain* also brought with it the advantage of providing an entire economic package for irrigation projects: The company owns food processing

factories that will guarantee a market for the onions or the tomatoes that are grown by Indian smallholders. This reduces the risk of drip adoption dramatically.

The leading Israeli irrigation companies are now all owned by foreign corporations. After Jain Irrigation purchased *NaanDan* outright and *Mexichem* bought 80% of the Netafim corporation, the pattern continued with Kibbutz Gvat eventually selling controlling shares in *Plastro* to John Deere and Company in 2008. But their sales agreement also agreed to leave the Israeli manufacturing facility unchanged for fifteen years. In short, Israeli know-how and ingenuity still drive much of these multi-national giants' corporate strategies.

The New Generation of Israeli Irrigation?

Uri Shani is among the most acclaimed and innovative researchers in the area of water and irrigation in Israel. After serving as the senior researcher at the R&D station in the southern Arava, and Farm Manager for dairy colossus, Kibbutz Yotvata, he was recruited by the Hebrew University Faculty of Agriculture, where he taught and oversaw a range of experiments involving drip irrigation. In 2007, he was appointed to become director of Israel's Water Authority, the first academic to ever hold the post that oversees Israel's water resources. Upon completion of the position in 2011, he opted out of academia and established several new "start-up ventures" in the area of irrigation and water management.

Sciroot

The first was an idea he developed while still the Hebrew University, a concept that was originally called "Irrigation on Demand". The product involves a sensor that is embedded into a drip system designed to address fundamental inefficiencies facing even the most sophisticated, conventional drip irrigation systems. That's because the precise amount of water required by crops to maximize yields can vary dramatically in a single field due to the spatial variability in field conditions as well as vicissitudes in diurnal weather and seasonal climates. Traditional drip systems are able to deliver a high percentage of water to root zones of plants. But they cannot tell farmers the actual amount of water plants need at a given time.

As a result, farmers frequently overcompensate and excessively water crops, as a precautionary or "better safe than sorry" agricultural strategy. Crops may end up receiving the required amounts of water, fertilizers and chemicals – but by definition, substantial quantities of inputs are wasted. Cumulatively, the runoff of nitrates and other chemicals can exacerbate water quality problems; Farmers incur significant and unnecessary costs.

Shani's idea was to build a sensor into the dripper that could tell farmers the actual conditions at the roots with regards to moisture and water availability. Emitters are covered in a geotextile cloth that allows for roots to grow inside of a tensiometer which then signals the actual soil moisture at the specific site. This offers a highly accurate measure of conditions between the root zone and the soil, allowing for a far more precise irrigation regime.[152]

Initial field trials showed that the system works well and saves significant quantities of water. Table 2 shows comparative results from the company's recent field trials. At the same time, the sensors and associated information management system are relatively costly,

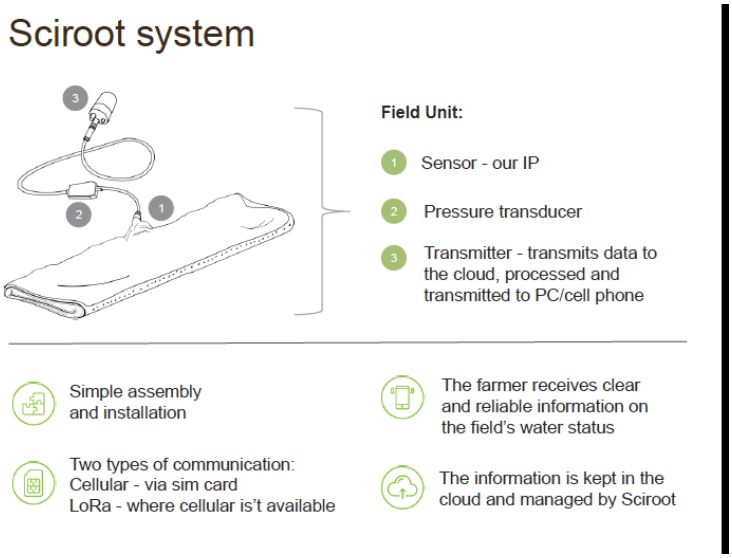
raising the expense of drip irrigation systems to a level which may be beyond the economic capacity of many farmers, especially in Africa. Yet, as water scarcity increases, or as farmers begin to rely on desalinated water, water prices will rise and the cost-effectiveness of such systems will become more compelling.

Yield & WUE in Sciroot active (2010-2016)

Crop	Irrigation method	Irr (mm)	Yield (Ton/Dun)	WUE (Kg/mm)
Onion	Sciroot	460	3.6	7.83
	Farmer	572	2.8	4.90
Sunflower	Sciroot	395	4.52	11.44
	Farmer	455	4.16	9.14
Lettuce	Sciroot	84	4.08	48.6
	Farmer	86	3.95	45.9
Radish	Sciroot	60	1.97	32.8
	Farmer	106	1.85	17.5
Corn	Sciroot	384	1.51	3.93
	Farmer	487	1.47	3.06
Potato	Sciroot	245	3.5	14.3
	Farmer	565	3.58	6.34
Tomato	Sciroot	526	12.21	19.6
	Farmer	568	11.7	20.6
Pomegranates	Sciroot	211	22	104
	Farmer	309	22	71

The product was developed under the auspices of the agrichemical conglomerate, Adama Company (Formerly Machteshim Chemicals) and the name of the product was changed to "Sciroot". The focus of the new product was also modified, with the present emphasis placed on providing critical information, in real time, to farmers about plants' water availability in order to make for better informed management decisions. Pilot efforts suggested that many farmers were loath to concede managerial control over key decisions about how to best use their irrigation and fertigation systems, even though empirical experience showed that yields would probably improve. Shani likens the situation to autonomous vehicles, where the technology is already in place and ready, but the public is not. He is also concerned about issues involving liability: if for some reason the smart irrigation system fails or is run improperly and crops are lost due to irrigation snafus, users may hold the company responsibility for failure.

Accordingly, the product is now marketed as a state of the art system for "Accurate and reliable field and crop information analyzed, using 'big data' technologies that serve farm and market decisions for effective management." The company claims that competing sensors, lack reliable field representation, require calibration, and are more expensive. By contrast, the Sciroot product purportedly provides "smart, accurate, inexpensive system for sampling soil volume and active roots for a variety of vegetables, field crops, orchards and soils, under a range of climate conditions, allowing for reduced consumption of water usage and greater yields." Figure 6 shows the components of a basic Sciroot unit.



While it would seem that such high-end irrigation innovation would only be of interest to capital intensive, sophisticated agribusiness operations, Shani believes that in practice, the system is simple enough to be used by farmers from developing countries who are beginning to move beyond subsistence levels to commercial levels of operation. A single Sciroot sensor is not inordinately expensive. By 2019, the total unit costs for the ceramic sensor, which includes a transducer and a transmitter, will come down to $60.

Ndrip

Shani's more recent innovation is on the other end of the technological drip irrigation continuum: it involves a simplified and far cheaper approach which Shani believes is tailor made for the reality – and budgets -- of most African smallholders. It constitutes something of a response to what Shani believes to be the flaws and failings of family drip systems.

Shani taught graduate students in soil and water science for many years at Israel's leading academic agricultural program at Hebrew University. Not surprisingly, his perspective is steeped in the "big picture": Today, more than fifty years after the first drip irrigation was established, only about 3 percent of irrigation worldwide utilizes drip systems. From his perspective, this constitutes an enormous failure.

Flood irrigation is a 4000-year old, highly wasteful practice, that started with the ancient Samaritans. And yet, it remains the predominant irrigation technology, still used by 85% of the world's farmers. In Shani's view, this reflects drip irrigation's glaring disappointment as a marketable product. With growing populations and mounting consumption levels, water shortages -- from Texas to California; from Senegal to South Africa -- grow worse every year. Much of the reason for this is the inability of decision makers across the planet, to raise the price of water. The public expects water and food to be cheap. These expectations are unlikely to change in the foreseeable future.

This means that new ideas and new approaches need to be adopted to move the world away from flood irrigation's enormous inefficiencies and towards a more sustainable water management strategy. With some 75% of the planet's freshwater utilized by agriculture for irrigation, the vast majority of water used by humans is utilized at a 30% efficiency level.

Shani believes that the most effective way to resolve the pervasive water scarcity around the world is to transform flood irrigation practices and introduce an entirely different approach to drip technology.

He describes the origins of this insight: *"I was hiking in the high mountains of the Sinai desert with my friend Motti Harari. All of a sudden, I realized that conceptually we were going about it wrong. I saw the local Bedouin population there using an extremely primitive irrigation system. But it seemed to work. They transfer water, through simple black polyethylene pipes for distances as far as a kilometer and a half to a fruit orchard. There they watered the trees, either through a dripper, or simply through a hole in the piping. It's a simple and not particularly efficient system. But again, it seemed to work. And it was surely preferable to the alternative, which is dragging water in buckets or using flood irrigation. Carrying water in a desert environment in buckets over a kilometer is backbreaking work – and wear farmers out. Alternatively, flood irrigation loses far more water than it delivers to plants. Both approaches are fundamentally unsustainable."*

Netafim developed what they believe to be a simple FDS system to support farmers facing such dynamics. But Shani sees it as based entirely on the perspective and technological approach of its original irrigation systems. Because the system ultimately requires pressure to run (even if it is provided by gravitational pull) the final dripper on a line can't be more than 70% lower in height than the initial dripper. There are also water quality constraints which require filtering. This means that the system design, even in its simplified form, is far too complicated and too expensive for smallholders from around the world to adopt. The scope of the family systems is also too small to be really helpful to a farmer who needs to provide food for himself -- much less for a farmer who wants to produce commercial yields. Its range is better suited to a garden than to even a small agricultural plot.

"I said to myself: we need to make a truly inexpensive system that does not run on pressure. We need a pipe through which water can pass. Who cares if the last dripper is 70% lower than the first one. The main thing is that it delivers the water to the trees. Of course, as a product you'll earn far less per unit. But you'll be able to sell many many more units."

The resulting product was patented as the "*NDrip*" and it constitutes a fundamental break from the prevailing Netafim drip paradigm. A black polyethylene pipe of modest quality is embedded with drippers that release water to plants, powered solely by gravitation pull: No pumps or associated infrastructure are required; No filters. On the one hand, the low-quality system lasts for only one year (but then can be fully recycled). The system then needs to be replaced on an annual basis. But relative to existing family drip systems, it is very inexpensive. While it appears as if the dripper is a "low tech" product, in fact there is tremendous engineering creativity and considerable empirical field trials behind the design.

The ease of application of the system becomes clear when comparing the different drip irrigation models. Today a typical, normal dripper requires ten meters of pressure. You need 4 more meters of pressure to operate a filter. All told, 15 meters of pressure are considered a minimum for a small drip system to work. Family drip systems, typically rely on 2 meters of pressure, which is why water frequently will only reach a 15 meters radium. But the system also requires a filter, so the water must be raised even higher. By way of contrast,

NDrip system can operate successfully with a mere half meter of pressure. Indeed, the dripper cannot be laid too far below the water source because the system is not designed to withstanding high pressures.

An *NDrip* production facility has been established in the Israeli development town of Beit Shean and the first system is already operational in a large farm in Swaziland. Demonstration sites are soon to be established in Texas and in Arizona along with Australia. There is talk with the European Investment bank to make a major grant that will allow for introduction of the technology to agricultural operations in Central Asia. The company's ultimate vision is to make these systems widely available in Africa,

Like most other irrigation experts, Shani also expects a reasonable level of organization at a village/community level to allow for his system to successfully penetrate the African markets. Because *NDrip* systems are so inexpensive, it would *not* make sense economically to provide technical support to individual users in remote locations, whose farms are often less than half a hectare in size. A critical mass of users is required for technical extension.

An important point which Shani emphasizes is that *NDrip* should not be perceived as competition for consumers of *Netafim's* conventional *Netkit* or the comparable *NaanDan Jain* system. Rather he targets farmers who are already using flood irrigation, but who are disinclined to make investments in conventional drip systems. From a marketing perspective, the company envisions focusing on large agricultural operations in Africa. The assumption is that if the smaller operators witness NDrip's "proof of concept" in the fields of their larger, more prosperous colleagues, they will be highly motivated to acquire the technology for themselves. Smallholders are not expected to become early adopters, even though it is hoped that eventually, they will be the primary beneficiary of this new, low-cost approach to drip irrigation.

2) Integrated Pest Management

Based on the Israeli experience, especially in dryland agriculture, notwithstanding any number of precautions -- from double doors in greenhouses to the full array of biological controls --when the truly warm weather arrives, pest infestation is ineluctable. Ultimately farmers will need to resort to using some chemicals to control the outbreaks – even though this should be a last resort. Integrated Pest Management (IPM) is pragmatic in this regard: any chemicals used should be prioritized by their low toxicity and persistence while applications should be as parsimonious as possible. Even farmers who are the most enthusiastic advocates of biological controls in Israel prefer to speak about pest *suppression* rather than pest *eradication*. Eternal vigilance is perhaps the most critical component in any effective pest control strategy – more than reliance on any chemical or natural predator per se.

Biobee's biological solutions

In a relatively remote corner of Israel, near the border with Jordan, near the ancient town of Beit Shean lies Kibbutz Sdeh Eliyahu, home to *Biobee*. For 35 years this company has been steadily expanded the "tool kit" available locally and internationally to support integrated pest management strategies and the biological controls of pests. *Biobee* initially began mass producing beneficial insects and mites. This still constitutes the company's core product. But

over the years it has expanded to other areas. *Biobee's* chief scientific officer Shimon Steinberg is something of a visionary and a charismatic enough scientist to post a highly engaging Ted Talk about his work that has attracted 30,000 views: (https://www.ted.com/talks/shimon_steinberg_natural_pest_control_using_bugs).
Steinberg has been with the company for 28 years and has followed it through the many of phases of its evolution.

In addition to the beneficial insects and mites, in 1991, *Biobee* started raising bumblebees for pollination services. Soon thereafter, in response to concern about an outbreak of the Mediterranean Fruit Fly in the Central Arava Valley, it became the first place in Israel to offer Sterile Insects Technique capacity. This allows for the release of flies who can mate, but are infertile due to radiation treatment. Populations plummet as a result. In retrospect, the initiative is credited with saving the area's red pepper crop. During the 1990s, given the high export prices, as much as 2000 hectares of Israeli farmlands went over to pepper production. Most of the peppers were grown in the arid Central Arava region. After a collapse in prices in the year 2010, the amount of cultivated lands dropped to almost of half of peak levels.[153]

In 2013, the company added biopesticides to its lists of products. The use of essentially organic entomopathogenic fungi and nematodes can protect plants from pest infestation. To this they added distribution of botanicals such as natural pesticides from Neem trees that are purchased in India as well as pheromones (imported from the American company: ISCA) and other techniques for disruption of pests natural mating processes. Then, the company began to use Mycorrhizal fungi as an inoculant for soils and crops and other bio stimulants to strengthen plants against pests. Finally, some three years ago, *Biobee* began to develop an entirely new product for farmers: the raising of insects as feed and food. The company's primary focus is in producing "feed" by breeding the "black soldier fly" (BSF).

While all of *Biobee's* products might be helpful to smallholders that face pest problems, Steinberg believes that the black soldier flies offer a product which could be revolutionary for them economically. These remarkable flies eat anything that resembles organic waste that is decaying. This could be agricultural residues, manure, industrial or human wastes. After they are ground up, the BSF maggots make first rate insect meal. Their oil is rich in anti-oxidants. Anything that the flies leave behind in terms of waste, makes excellent fertilizer. Thus far, *Biobee* has managed to develop fifteen separate commercial products and uses for BSF production. At the same time, the flies can solve some of the acute sanitation problems, which are so vexing in rural settings.

The fly is highly adaptable and found around the world. A company near Cape Town South Africa is probably the world's biggest BSF producer. But it focuses primarily on sanitary services. *Biobee* is convinced that first and foremost the fly has tremendous potential as feed for animals, especially in the world's enormous pet food market. And while recently there has been considerable "buzz" about the fly in the insect producing world, Steinberg argues that relatively few companies are making a meaningful investment in developing methods for commercial breeding. As a "35-year old startup venture" *Biobee* is doing just that, with the idea of providing a product that could be perfect for small farming operations.

Biobee is yet another Israeli company that was born and raised on a kibbutz. Today 82% of the company is owned by the Sdeh Eliyahu community. Of the company's 350 workers, only about a seventh (50) are actual kibbutz members. Six subsidiaries have been established as smaller production facilities around the world: in Chile (with its focus on bee pollinators for blueberries) Columbia (that specializes in spider mites to protect roses) with a similar new daughter company in Russia. *Biobee* South Africa, located near the Zimbabwe border, provides biological pest control solutions for citrus fruits, grapes, vegetables and flowers. *Biobee* also relies on its own distributors in Baja California Mexico and Atlanta U.S.

Today the company sees itself as the world's third largest provider of biological products and services to agriculture, after the Dutch leader *Koppert Biological Systems* and *Bioline*. While they are competitors, the companies cooperate regularly, with many *Biobee* products distributed by their colleagues. For instance, three major shipments a week of Israeli grown predatory mites are sent to Los Angeles where *Koppert* runs its American operations. For 25 years, the Israeli-born bugs have kept much of California's strawberries free of the pernicious spider mite. Within at least 72 hours of their leaving the Jordan Valley, the mites are in the fields of California taking on the local pests. *Koppert's* California operation is also the reason why Biobee decided to establish its U.S. facility on the American east-coast, so as not to compete unnecessarily with its Dutch colleagues.

Minute Pirate Bugs, ready to take on Western flower thrips: BioBee Packing house, Kibbutz Sdeh Eliyahu

Biobee's South Africa office is highly successful, but has little interface with local smallholders. This orientation is not unique in the field. None of the major biological control companies is seriously engaged with smallholders. For instance, *Biobee* conducts considerable sales in Cher Ethiopia. But this remarkable village's economy is based on a sophisticated and profitable agribusiness that exports roses. Steinberg believes that assisting smallholders will be difficult because biological control is complicated and is anything but a "launch and leave" operation. On the contrary.

There is constant technical assistance that biological pest control companies need to provide to farmers who typically do not know: "What is the balance between beneficial insects and

pests?" "Is there a need for chemically corrective measures?" "Is the dosage precise enough to prevent a non-target effect?" The disengagement with smallholders is unfortunate, of course, because the *poorest* farmers tend to purchase the *cheapest* pesticides (e.g., DDT) which are frequently the most ecologically destructive or harmful to human health.

Some 70 percent of *Biobee's* products are export, but the other third serve Israel's farming community. Local operations in Israel might serve as a model for emulation in other countries. Some fifty locals "scouts" (ten on the company payroll) support Biobee's work in the field across the country, visiting their clients once a week in season to assess the impact of biological treatments and the need for adjustments. This extension service allows farmers to avoid automatically spraying based on the calendar, and to respond to the actual insults presented by pests in their fields. Rather than unleashing a chemical arsenal, farmers can bring on the precise biological predator required. Once again, to deliver these kinds of products, as well as the critical technical advisory services for smallholders in Africa, requires organization at the village or regional level.

There are certain advantages to using natural predators in the controlled conditions of a greenhouse. Modern greenhouses involve capital investments that smallholders typically lack. Nonetheless, *Biobee* offers numerous products which are highly effective in open fields as well. Strawberries are just one of many examples. Israel is a small country, with only about 350 hectares of strawberry fields. Some 60% of them rely on *Biobee's* IPM strategy.

Biobee has become something of an attraction for the steady flow of visiting farmers from developing countries and agricultural officials participating in Israeli training programs. Typically, after learning the basics of IPM from Steinberg, they visit the *Biobee* factory and then go with a scout into the field. *Biobee's* partner who helped establish the company's Columbian subsidiary, was actually a participant on one such training course who grew highly enamored of the company's work.

One of the challenges to expanding IPM into African countries involves regulatory constraints and concerns about the release of exotic / invasive species. Not surprisingly, *Biobee* and its partners in Europe have found that as countries become more developed, regulations grow more stringent. Steinberg is quick to claim that he knows of no documented cases where introducing natural insect predators have created ecological havoc.

Cultivators – a non-chemical weed control strategy

If they are not destroyed, weeds compete for scarce resources, supplanting nutrients and water from the crop. There are a range of approaches to addressing the perennial challenge of weed control, including the age-old chore of human weeding. For the better part of a century, herbicides have been applied with great alacrity around the world. This input adds to the costs of production, exposes farmers and consumers to chemicals which by definition are poisonous and also can lead to development of resistance among plants.

Cultivators offer an alternative "mechanical" approach that remove weeds directly via tillage. The accuracy of cultivators for weed control is steadily being upgraded, primarily by agricultural equipment firms in Europe. Israeli researchers have begun to develop a range

of new cultivators which are both more precise and which can be utilized by smallholders with the benefit of tractors or plow-pulling farm animals.

Dr. Ron Lati, from the Volcani Institute's northern research station, Neveh Ya'ar in Ramat Yishai, divides his time between developing precision agriculture and mechanical weed control. As cultivators become more precise, farmers develop more meticulous abilities, so that their tilling can physically destroy weeds without injuring other crops. This is especially valuable when herbicide resistant weeds are not affected by the usual chemical treatments. While he reckons that the more sophisticated systems, such as autonomous, GPS-driven tractors will be more difficult for African smallholders to apply, Lati strongly believes that even modest farm operations will find the *cultivator* that he is developing to be cost-effective in the short term.

While typically, cultivators are considered machinery appropriate for large operations with John Deere tractors pulling a cultivator across six rows, in fact a range of blades developed by the Neveh Ya'ar team allow for applications by individual farmers without mechanized equipment. Early weeding operations subsequent to cultivation and prior to planting can be especially valuable because as weeds develop roots and gain access to greater food reserves, they can increasingly resist and recover from mechanical damage. Early treatment with cultivators can prevent germination of weeds altogether. After planting, the challenge is even greater given the importance of controlling weeds when they are not yet well-established.

Lati's new version: the "Finger Wither" cultivator, contains specially designed discs that can remove almost all vegetation outside the thin line of crop rows, where seeding takes hold. Here precise seeding also turns out to be critical: the more systematically that seeds are placed, the more complete the removal of weed vegetation can be and the closer to the crop plant cultivators can operate. The Israeli cultivator can be utilized quite delicately by an individual farmer. Hand-held weed flaming systems that can be utilized by individual farmers also are now developed by Volcani Institute's Neveh Ya'ar unit Flaming systems are an acceptable pest control system for organic farms as well, and have been used with great success in the cultivation of organic onions in Israel.

Lati claims that for agriculture to be sustainable, it is critical to look at weed control (and pest control in general) with a long, time horizon – rather than a yearly cycle. He tends to think in terms of periods between five and seven years. That is one of the advantages of basing smallholder weed control strategy on cultivators: it may cost farmers slightly more than the price of herbicides for a given year. But once the weeds are removed, they do not simply reappear the following growing season, making it a more cost-effective approach over time.

According to Lati's perspective, herbicides, per se, are not the enemy. Rather, the problem is the prodigious amounts of chemicals that farmers end up using to protect their crops. Concerns can be expressed that mechanized weed removal systems will supplant agricultural workers who weed manually – a human resource who may be relatively plentiful in smallholder communities, Lati, however, believes that millions of people can be spared,

what has always been some of the most backbreaking, dull and unpleasant work for farmers, using their time and physical resources for other, more productive ventures.

3) Animal Husbandry and Dairy Science

The Volcani Institute runs an *Institute of Animal Science* which is headquartered on the campus of Hebrew University's Faculty of Agriculture. The Institute is home to 22 researchers, divided into three departments:

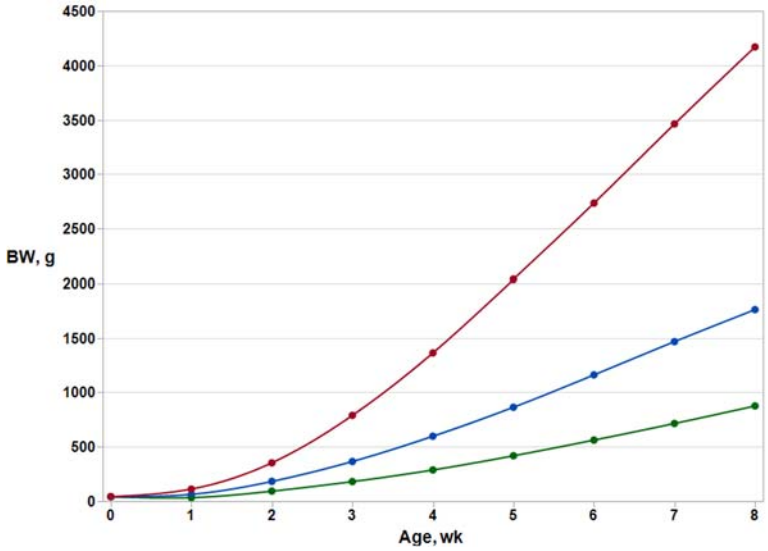
- The Department of Poultry
- The Department of Aquaculture Sciences
- The Department of Ruminant Sciences.

The Institute also runs its own farm, located at nearby Beit Dagan on the main Volcani campus, which was established to support the Institute's research agenda. The facility contains 2500 hens, 400 sheep with a stock of 500 lambs that are sold for meat; 250 milking cows. 200 – calves and non-milking cows. With its prize livestock sold to farmers for profit, the farm's turnaround is sufficient to make it an economically self-sufficient part of the research unit.

Many of the Volcani Institute's innovations in animal husbandry may prove valuable for developing countries. For instance, a common mutation that causes blindness in lambs has been identified and stocks are now monitored to select against the mutation. As goat and sheep cheese becomes more popular, the animals have been bred for higher milk production. But it is *herd prolificacy* that may offer the single greatest contributions to food security. While traditionally ewes gave birth to a single sheep or to twins, Dr. Elisha Godwin has increased the average fertility of sheep from 1.4 to 2.7 lambs. This newly developed Afec Awassi sheep strain has already been introduced into flocks of the Israeli, Bedouin community, increasing the profitability for local shepherds dramatically. Presumably, the many pastoral communities in Africa who are suffering from reduced rangelands due to population growth as well as from desertification could benefit from enhanced fertility.

Similarly, Volcani's poultry unit has dramatically increased the growth rate of Israeli chickens. Today it takes 38 days on average for a chicken to reach 2.5 kilograms; 30 years ago, it took 75 days -- literally twice as long.[154] This kind of progress can make a tremendous contribution by putting poultry in the center of future food security solutions for Africa. Figure 7 shows the genetic improvement in livestock growth that has taken place in Israel.

Genetic improvement in livestock 1957-2005 with three strains of chickens



Zuidhof et.al. 2014

Volcani researchers have also contributed to significant progress in providing low-cost food for dairy herds without harming their health. This involves developing more nutritious seeds and producing food from other farm residuals, such as pomegranate peels or residues of olive oil production, residues which would otherwise be thrown away. The new feeds exhibit tremendous advantages in terms of reduced oxidative stress and strengthening herd immune systems. Also, the new strains of high-yield, rapid-growth sorghum and cephalaria being developed can improve foraging conditions for small dairy farms in Africa.

An area where Volcani research may be especially valuable for Sub-Saharan African involves reduction of thermal or climatic stress for livestock in drylands, especially for dairy cattle. Study results show a range of optimal feed regimes that positively affect milk production. Another line of research involves the precise monitoring of cows, whose every step is measured and a range of physiological parameters (heartbeat, temperature, etc.) constantly monitored. These systems are probably not very relevant to smallholders with modest means and modest-sized herds. But other innovations are far simpler to implement, such as cooling strategies which integrate optimal shading and showering schedules.

Like livestock researchers everywhere, the Volcani team seeks ways to reduce the carbon footprint of cows and sheep, with a particular emphasis on studying the molecular/genetic level. Experiments evaluate the bacterial communities involved in digestion directly rather than focusing on adjustment of diets. Researchers explore the development of rumen bacteria population from the birth of the cow until its maturity. The goal is to reduce methane production by developing transgenic bacteria, with increased hemi-cellulolytic qualities for improving ruminant nutrition.

An important part of the national dairy strategy involves the “Herd Book” – a national genetic record which contains 85% Israel’s cow population. The book allows scientists to provide critical information to farmers at the “cow level”, enabling them to make optimal management decisions, especially in the area of health regulation. The book also allows the

Volcani dairy team to optimize genetic makeup to maximize economic benefits from local herds. By identifying the male bulls with the potential to create the highest quality of milk, the quality and quantity of milk production nationally continues to improve. African countries could adopt similar programs of monitoring and insemination based on Israeli genetic advancements.

Research conducted in the area of poultry development may be particularly germane for dryland agriculture, where conditions are only getting warmer. For example, Shelly Dweck studies ways to make chickens less prone to heat stress and assesses the ability of food additives to help them overcome high temperatures. One of the fascinating areas of present research at Volcani's Institute of Animal Science involves the manipulation of embryos at developmentally sensitive times to make chicks more resilient. The goal is to influence the gene expression and phenotypes of poultry embryos and newborns (including chickens, turkeys and laying hens) to induce long lasting physiological memory, by using epigenetic adaptation. This can enhance resistance to environmental changes in temperature, oxygen partial pressure. etc. Research suggests that such robustness can be achieved through heat treatments or exposure of pregnant hens to carbon dioxide, creating a more resilient cardio-vascular system, able to withstand tougher environmental conditions.

Future research challenges in animal husbandry which appear promising including the adding of special qualities into life stock produce. For example, there has already been significant progress in increasing the level of protein in milk or creating a hypoallergenic egg. Another promising area of work involves influencing livestock gender. Among the central challenges in poultry research is the problem of male chicks, which are essentially superfluous in the egg industry. Israeli researchers are now able to hatch almost entirely female chickens through genomic editing. This involves the basic science of epigenetics, where the environment (for example freezing) effects the breakdown and distribution of the proteins. The fundamental research question is: how does the environment affect genetic inheritance. The research methods used are certainly "hi tech", but the Volcani researchers are quick to emphasize that they do not involve genetic modification, due to marketing concerns. This cautious inclination also informs the development of grains and other seed varieties.

The *Animal Science* Institute also researches fish, although the number of active researchers in this area is relatively small. Nonetheless, there are two areas of work which might be valuable for smallholders. Fish ponds have great potential in Africa, China as well as India. The objective of much of the Volcani unit's research involves creating fish that are a single size and a single sex. Controlling the gender of fish prior to hatching is important because unisexual ponds contain fish that don't waste energy on matters involving courtship and mating. It also reduces the need for hormonal treatments and contributes to a more homogeneous size of fish in the fishpond and later in the market.

The second area of fish research involves creating optimal ecological conditions in ponds for growing fish and absorbing their wastes. Researchers create closed systems, where fish wastes and soiled waters can then be utilized as fertilizer and irrigation waters. There are also impressive findings in research that seeks to improve fish survival in extremely brackish water. This will allow fish farmers to utilize the brine water released from desalination plants

and other high salinity ground water sources, which are typically deemed unsuitable for drinking or irrigation.

4) Post-Harvest Food Protection, Storage and Food Safety

With an alarming 1.3 billion tons of food on the planet defined as "lost" every year, reducing wastage and maximizing the amount of produce that is actually consumed, is a critical global challenge, beyond increasing yields [155] The FAO estimates that in developed countries some 670 million tons of food is lost, while a comparable quantity – 630 million tons – is wasted in developing countries. But the dynamics in these two worlds are entirely different: Most of the loss in develop countries involves food thrown away by households who simply buy more food than they are able to eat. But in developing countries, and in Africa in particular, 45% of the food is lost by farmers who are unable to market the crops they grow.[156]

Often crops spoil before they can be sold and consumed. Tragically, this phenomenon is not uncommon in countries where food shortages are a major source of mortality and morbidity. Food poisoning also constitute a serious public health insult. In a 2017 study, the World Health Organization estimated that 420,000 people die each year, worldwide, due to contaminated food.[157] Providing *safe* food from "farm to table" is becoming an increasingly important policy objective all over the world. It is no surprise that concerns about safety and meeting rigorous import standards almost limit the export potential of African produce. Israeli scientists have developed numerous innovations to address these unfortunate dynamics.

The *Volcani Institute* is probably among the top three research centers in the world developing post-harvest practices and pursuing related plant biotechnology research. Other excellent centers can be found at the University of California at Davis and New Zealand's *Institute for Plant and Food Research*. The Volcani research team is substantial by Israeli standards. Thirty years ago, there were 21, Ph.D. level researchers working in the department of Postharvest Science. Even though the number today has dropped to 14, it remains a particularly innovative and productive research group. The unit works in areas assessing the physiological, biological and molecular makeup of fruits, vegetables and flowers while developing a variety of measures to extend their shelf life.

Professor Elazar Fallik is one of Israel's leading experts in the science surrounding post-harvest food protection, with research projects in a range of related areas. These include: control of post-harvest disease for numerous vegetables, improving the resistance and robustness of crops,[158] reducing water loss in fresh vegetables, development of hot and cold quarantine treatments in produce and the use of the synthetic plant growth regulator 1-MCP,
to inhibit ripening processes. "*Basically, what we do here is 'cheat nature'*, he jokes. That's because the technologies developed by Fallik and his colleagues extend the fruit and vegetable shelf-lives far beyond their natural longevity and make sure that they continue to taste good. Their research includes manipulating the ripening process, not only for enhanced longevity,[159] but also for improving their natural taste and smell. [160]

Professor Elazar Fallik, at his Volcani lab with fresh, perfect preserved, five-week old peppers

Fallik is convinced that yields could grow and food loss decrease significantly in developing countries even without utilizing the scientifically sophisticated treatments that Israeli farmers have integrated into their practices. While new modified atmosphere packaging, can help, low-tech knowledge may be even more important.

For instance, for produce to last, it is critical during harvests that vegetables and fruits not be pulled off the vine, but rather are neatly cut using secateurs (garden clippers). These should be sharpened once a week and sanitized once a day. Gloves will prevent fingernails from piercing or damaging the fruit itself. When fruit is laid down, it should be done so gently (rather than tossed into a bucket) and it should be stored in the shade. If trees are not around, temporary shelters should be built in open spaces to provide this cover. (Caves also can do the job.)

Lining wicker baskets with newspaper can avoid piercing from errant bamboo strands and removal of all nails from the basket can prevent damage to produce. If a fruit or a vegetable has mud on it -- once exposed to rain -- it will begin to rot. Farmers should be careful not to stack baskets of produce, lest they crush some of the previous fruits. When transporting produce to market, putting cushions in wagons to prevent bruising can also be critical. And today, with the advent of small solar energy systems, installation of refrigeration systems at the village level is finally feasible, even in remote, destitute regions. Such cooling systems for storing produce will soon pay for themselves rapidly in terms of expanded sales.

"*We teach these farmers at what hour to pick the fruit; how much and at what stage of ripening. Sanitation is also essentially low-tech, but extremely important: if done correctly, everything else improves."* Fallik explains. Picking fully ripe fruit in the field is a sure recipe for rotten produce at the market. And storage matters. During training sessions with African farmers, a simple experiment is presented by Israeli experts to make the point: Rotting fruit that had been

left in the sun is compared for quality with preserved fruit that has been shaded. The results speak for themselves.

In designing post-harvest protocols, produce is typically divided into two groups: pre-climacteric fruits and climacteric fruits. Once climacteric fruits begin ripening and ethylene begins to trigger cellular respiration, the process is largely irreversible and it is prudent to expedite marketing for immediate consumption. For a small farmer, this means that the two types of produce require different harvest strategies: those that become climacteric and ripen quickly on trees or in the field (such as apricots, melons, bananas and apples) need to be picked before they become rotten. Other fruits, like avocados, can last for longer periods on the tree as long as they are not picked.

After harvesting, while fruit is still pre-climacteric, it can usually be stored for extended periods, given appropriate cooling and chemical treatments. Applying MCP increases the potential storage duration dramatically, with apples and persimmons effectively stored for as long as 14 months. Cooling at *appropriate temperatures* is especially important, as every fruit and vegetable has an optimal temperature at which it should be stored. These are highly diverse: apples are best stored at cold temperatures of 1 degree and stay fresh for over a year; when stored at 10 degrees cucumbers can also last for long stretches. (When kept in a family's refrigerator – typically at 4 degrees – however, cucumbers will quickly begin to rot.) Both eggplants and tomatoes should be stored at 12 degrees, but never in the same room! Colored peppers store optimally at 7 degrees, while green peppers should be kept at 10 degrees.[161] Mangos last well at 11 degrees; dates should be stored at temperatures below zero because of their high sugar content. And some fruits, like strawberries will never last longer than two weeks no matter how they are stored.

If no refrigeration is available, utilizing packaging that contains 1-MCP can extend the life of fresh produce, even in the absence of cooling. Understanding these dynamics and adjusting practices accordingly is often the difference between a prosperous farm and one that goes bankrupt.

There are many commercial projects spawned by the Volcani Institute in this context. The post-harvest research team has helped develop a series of plastic bags and wrappings that prevent condensation of water in packaged fruits and vegetables. The Gates Foundation found that storage of produce in airtight bags – tripled layered –– cuts crop loss by 25%. While these bags can cost as much as two dollars, they can hold 100 kg of produce. The extended lifespan of fruits and vegetables usually can increase the income of farms by up to 50%..

Utilizing such post-harvest products can reduce the logistical costs associated with transporting produce, increase quality and preserve freshness. The packaging essentially creates an optimal range of oxygen and carbon dioxide concentrations for each fruit and vegetables which slows the ripening process and pathogens or decay, while preserving taste. In addition, when the relative humidity is kept at 90 to 95% shriveling, dehydration and loss of weight can be prevented.[162]

Some twenty Israeli companies are presently developing technologies for storage,

production and contamination tracking in addition to postharvest sterilization. Most important is probably StePac, a company recently acquired by the Johnson Matthey Group but that retains Israeli research facilities. StePac's packing is called Xtend – and it is "tailor made for each specific vegetable, fruit or herb, ensuring extended shelf life whilst maintain produce freshness, taste and nutritional value." The company's product line includes bulk liners, preformed retail packaging and bin liners for produce.[163]

There are other commercial outcomes from post-harvest unit's research. Based on their findings, that a brief rinsing of fruit in *hot* water increases its shelf life, the biologists and the mechanical engineers at the institute developed a relatively low-cost cleaning machine that rinses and brushes some twelve different types of fruits and vegetables.[164] The process is important for extending storage capacity, as the treatment eliminates pathogens that cause surface decay, while maintaining fruit quality during prolonged storage and marketing. Their research confirmed that hot water rinsing and brushing was less costly and more effective than commercial, vapor-heated treatment systems, especially when high temperatures combine with short treatment times to minimize heat damage.

The rinsing machine developed by the team of biologists and engineers at the Volcani Institute is largely produced for Israeli farmers, but the export potential seems to be self-evident. The rinsing machine recycles a third of the water it uses in the cleaning process. The machine received the vaunted Kaplan prize for innovative invention. Today there are 150 machines operating in Israel that utilize the hot water immersion treatment and brushing for vegetables for a range of crops including peppers, mangos, avocados, citrus fruit, tomatoes, melons and pitayas (where it even takes out the thorns). Best estimates suggest that the extended lifespan of produce creates revenues that allow for return of the entire investment within two years.

Amnon Lichter is head of Volcani's Institute for Postharvest and Food Service. Lichter has a particular interest in promoting projects in Africa. Indeed, in conjunction with a team at Iowa State University, he submitted proposals to the Rockefeller Foundation to utilize Israel's post-harvest technologies to increase smallholder capacity. Specifically, they have projects "ready to go" that would help Kenyan farmers extend the shelf-life of mangoes and bananas, improve post-harvest protection for tomatoes in Nigeria and implement storage protocols for cassava.

While Lichter recognizes that the infrastructure available for storage is completely different in developed and developing countries, he believes is a challenge that can be overcome. For the cassava, a detailed proposal has already been prepared to that end. The general idea would be to store produce from an entire village in a central facility which only requires a sufficient shaded space that can be kept entirely dry. With increasing availability of modular solar-power systems, produce could be kept fresh in a refrigerated village storage facility for longer periods. This would make farmers less dependent on the vagaries and vicissitudes of weather, as well as the manipulative middlemen who essentially give African shareholders one "shot" to sell their produce. For example, if cooling can be provided at 12-15 degrees, mangoes would last for 4 to 6 weeks. This temperature is also appropriate for keeping bananas for at least two weeks before ripening begins.

There is also much that can be done post-harvest, using disinfection to preserve food, as opposed to fumigation. The ripening of tomatoes, for example, can be drastically slowed simply by exposing them to appropriate gases in a closed container that makes them less susceptible to the effects of ethylene. It is very common in Africa for there to be a surfeit of tomatoes that ripen all at once, even though in most locations, the fruit there can be grown year-round. As a result, often the tomatoes must be sold right away, even when prices are pitifully low, due to excess supply. Within a month, fresh tomatoes may become entirely unavailable. The problem of inopportune ripening can easily be avoided by extending shelf lives by several weeks.

Lichter would like to create a consortium of international researchers to help Africans address their post-harvest challenges through low-cost solutions, with the department of Postharvest Science in the Volcani Center serving as the main hub. If a farmer is having a problem storing cucumbers until a reasonable price can be procured, the team could work on specific strategies. He calls for: *"A team of researchers who would think about specific solutions for the specific problems of developing countries."* Again, at the organizational level, this would require a cooperative model to get farmers in a community to work together to establish post-harvest infrastructures.

There are other teams within the post-harvest research group that focuses primarily on food and grain security. This group has amassed its own impressive achievements. Their work in grain storage has particular importance given the massive dependence of Israeli livestock production on seed imports. Today in Israel, 99.5% of the seeds imported reach their destination and are consumed, reflecting very sophisticated, post-harvest technologies and practices. By way of contrast, in many developed countries, grain losses can reach as high as 5%. In developing countries, 20% of grains are ruined before they can be sold or consumed.

As mentioned, contamination of food by pathogens constitutes a significant public health insult globally, contributing to an estimated 420,000 annual deaths.[165] Pathogens still destroy enormous quantities of food. These concerns and associated precautionary measures, limit agricultural exports from Africa and lead to wastage of perfectly good food. Some twenty Israeli companies are now developing postharvest technologies to improve food safety, in areas involving contaminant detection, sterilization and food tracking / quality monitoring,

For example, *Yarok*, the aforementioned Israeli startup, won a 2017 international agribusiness award (UNIDO ITPO) for its high-resolution, 45-minute, microbiological testing for freshness of foods. Another startup produces a pocket micro-spectrometer which can measure material composition in fruits and vegetables and thereby help reduce produce ripeness, spillage, and contamination. The instrument can also conduct nutrient analysis of animal feed. Another company utilizes breast-cancer screening technology to assess dairy contamination at the farm level. This is an area where Israeli market share in the agrotech business appears to be unusually high. Israeli companies attracted some 23% of the investment in postharvest innovations, worldwide, in 2015. The so-called *Supply Chain* sector, reportedly raised 8.3 million dollars in 2016.

5)Knowledge and Market Information Dissemination

While this report focuses on research and technologies taking place in Israel which might be applied in Africa – there are already several agricultural enterprises in Africa run by Israelis. In this final section, four such initiatives are presented. They are selected because they are designed specially to assist smallholders.

Farmster: Using Cellphones to Expand Smallholder Sales Options

A special 2017 issue of *The Economist* focused on how technology and agriculture considered the hypothetical potential of cell phones to cure market failures in Africa and improve agricultural performance.[166] One of the more innovative Israeli aggrotech startups, identified this potential years earlier, leading to the creation of *Farmster.* The company was started by Dr. Adam Abramson, a young academic expert in water development whose agricultural work in several African countries led him to an entirely new way of addressing what he considers to be the principle problem facing Africa's farmers.

The *Farmster* website opens with a description of "The Problem" at the heart of Africa's sluggish agricultural performance: In emerging markets, poor marketing and information channels lead to high post-harvest losses:

- 25% for grains
- 55% for fruits
- 45% for vegetables

Farmers and buyers struggle to find each other at the right time: the harvest. *Farmster* provides farmers without internet an SMS chatbot, developed by the company, to notify buyers about their crop before harvest. Those with smart phones can use the *Farmster* App to connect to an even broader range of market options.

Abramson sees the most fundamental conundrum facing Africa's smallholders as a scaling problem in marketing. This turns out to an extremely difficult logistical challenge. The objective obstacles facing most African farmers are formidable: They are geographically isolated; they do not have an internet connection; their economic circumstances are extremely precarious. The reality for a farmer who wishes to progress beyond subsistence levels is that there are very few venues for selling their produce. Often a single, so-called "*middleman*" or transport service provider, offers the only entry point for them on the agricultural value chain.

This means that even if a farmer enjoys a bumper crop, she faces an extremely inefficient road to market: The truck picking up her produce will travel long distances and make multiple stops along the way so that the produce may get to market in damaged condition. Assuming that she decides to utilize a truck, some 20% of the boxes on the truck will go to the middleman, off-the-top, in the initial barter. Essentially, the farmer assumes all the risk, does all the work, acquires all the inputs -- but gets a disproportionately low percent of the crop value.

These dynamics are not unusual worldwide, but are particularly conspicuous in Africa. It is very common for a farmer to grow produce and discover that the market is actually flooded just when she would like to sell. In a best-case scenario, return on investment of time and

resources will be extremely modest. Frequently, crops are simply thrown away for lack of a buyer. Because of these objective geographical and communications circumstances, there is very little planning in which farmers can engage. And there are many cases where they simply lose everything.

Abramson, originally an American, came to Israel after graduating from Harvard and then completed a doctorate in water development at Ben Gurion University. His doctoral research was conducted in Zambia and he then began to work in Zimbabwe and other African countries on a range of development projects. It was that there that the *Farmster* concept coalesced, a concept compelling enough to attract the attention of the Gates foundation, which provided him support through their *Farm Buddy* program.

Official figures in 2018 suggest that while officially Africa has 40% internet access, for smallholders, this is a gross overstatement because it includes cities and major towns. Abramson estimates that in the rural sector, only 10% of farmers have access to the internet and even this involves a highly unreliable level of service. At the same time, cellphone infrastructure throughout the continent is reasonable: there is close to 100% access to a cellphone, even as it is usually a very rudimentary cellphone model, based on old technology. [167]

Farmster establishes an "SMS gateway" into the internet, by creating a chat bot that becomes an automatic conversation. Abramson's assessment suggests that today, some 70% of African farmers can read, with the younger generation reaching higher educational levels than their parents. The farmer, alone (or with the help of a more literate child or friend), can type in "tomatoes". Then a message will be sent back of where the particular product is being sold, what present prices are, etc. Response is in real time, so that farmers can make decision with the nimbleness required to take advantage of market opportunities.

Abramson reckons that without massive investments, the problem of scale for smallholders will be insurmountable as there are limits to reaching the populations presently locked in the poverty cycle. This became particularly evident to him during his dissertation work where he created a microfinance program in Zambia: *"I said let's look at a village: In practice what are their options? What do NGOs do under these circumstances? Well they start by minimizing their costs so they can reach as many people as possible. Of course, in the long run a 5,000 dollar well with a 500 dollar pump is a more productive infrastructure investment. But only two farmers might benefit from that."*[168] *Farmster* has the potential to end the isolation of hundreds of thousands of African smallholders.

The company began pilot operations in Tanzania and initial results are promising. Local staff, engaged some 600 farmers who quickly posted 800 crop listings. At least half of the participating farmers are women. The organization trains agents in rural villages and then they onboard their neighbors. The organization is able to find optimal pricing for the different crop listings and ultimately expand the pool of buyers, creating a stiffer and more reliable demand. While still in its nascent stages of development, proof of concept seems sufficient to justify a more significant investment in this innovative venture.

Farmer Kits: Amiran Kenya

Amiran Kenya defines itself as "the largest one-stop shop for full agriculture solutions in East Africa." Established in the 1960s, by Israelis it was acquired by *Balton CP*, a British company with activities throughout Africa, including offices in Rwanda, Ghana, Tanzania, Zambia, Uganda, Ethiopia and Nigeria. Its initial involvement was establishing Israeli designed greenhouses throughout Africa. Today the company points to some 3,000 hectares of intensively cultivated lands in greenhouses it established. The company also supplies a range of Israeli products in its basic *Farmer Kit*, including different-sized *Netkit*, Family Drip Systems.

Eventually *Amiran* went on to provide a full range of products and services necessary for successful modern agriculture in Africa. It has its own nurseries, and runs 300 stores (in Kenya alone), supplying fertilizers, irrigation packages, pesticides and even post-harvest treatments – based on the growers' needs. Some 30 to 40 percent of fertilizer sales in Kenya are facilitated through *Amiran*. The company differentiates itself from other conventional agricultural suppliers by offering farmers workshops and seminars, which can accommodate up to 200 farmers at a session. The training focuses on solving a range of problems and introducing management practices and a range of products for expanding yields. The company has had success in helping farmers in Kenya to move beyond single seasons to multiple crops on their lands. While its greenhouses initially focused on vegetables, especially tomatoes and cucumbers, today *Amiran* supports coffee and avocado farming.

Ron Yariv is the Business Development Manager for *Amiran Kenya*. The company has some 400 workers just in its Kenyan branch of whom 10 to 12 are Israeli. The rest of the management, including some 60 agronomists, are local Kenyans. For most of the company's history it focused strategically on large farming operations. Recently, however, the company established a smallholder department which offers a special "Farmer's Kit". Yariv believes that the major challenge in facilitating sales within this sector involves getting smallholders access to credit. At present, to outfit a one hectare farm operation with the full range of products -- from irrigation infrastructure (including a solar pump), to seeds and chemicals -- costs as much as 5,000 to 15,000 dollars. Based on the increased yields, this investment, can typically be returned by payments of 100 dollars / month. The company also works with local buyers and "middle men" to ensure that those making the investment will have reliable markets to purchase their produce and can return their investment expeditiously.[169]

Amiran is interested in partnering with an international aid agency to establish a village wide project to help smallholders. It envisions 100 to 200 farmers participating in such a community effort. Such a project would require a full-time manager on site at least during the initial year. For half a million dollars, Yariv believes that the company could quickly transform the agricultural economy within an African village using the latest Israeli technologies. Despite almost fifty years of work in Africa, thus far, *Amiran* has relatively few successes with smallholders. Perhaps that's why it sees partnership with philanthropy as critical to creating the critical mass required to engage this sector. As the company has such extensive presence in Kenya, it sees the country as the natural place to launch such a pilot initiative.

Netafim is highly appreciative of *Amiran* Kenya's work, and clearly sees it as a successful local sales agent. But its local representatives emphasize that *Amiran* already has such a strong presence in terms of merchandise stock available in Kenya, that in practice, it is has

probably moved beyond the model of "farmer's kit". Today many farmers simply show up at an *Amiran* warehouse and pass up prepared kits, preferring to mix and match according to their own perceived needs.

Support for Smallholders as Businesses "Tikkun Olam Ventures" (TOV)

Perhaps the most ambitious initiative where Israeli agrotech directly targets African smallholders actually originated in New York. In 2017 American businessman and philanthropist, Seth Merrin launched "*TOV" – Tikkun Olam Ventures* (literally: *Ventures to Repair the World*, based on the Jewish value of social engagement). Merrin's involvement in Africa began a decade earlier in Rwanda where along with his late wife, Anne Heyman, he established the Agahozo Shalom Youth Village. This high level, boarding high school offers a home to 525 students from the country's 1 million orphans (out of a total, national population of 11 million).[170]

Merrin's latest initiative began pilot efforts in November, 2017, providing low-interest loans to bring sustainable, pay-as-you-go solutions to small-scale farmers in Ethiopia. The project began on seven demonstration sites but is rapidly expanding. In addition to traditional extension assistance, the project seeks to "transfer of Israeli AgTech knowledge to experts, businesses, and smallholder farmers in emerging economies and the development of knowledge in Israel about both needs of smallholder farmers to promote innovation and about effective business models for reaching smallholder farmers."[171]

The economic model perceives participating the farmers "entrepreneurs" and help them create a business, through what is essentially a micro-financing of their agricultural or energy needs. *TOV* is designed as an "Evergreen Fund" where business loans are reinvested in additional technology transfer projects in other African countries. The initiative operates via the *American Joint Distribution Committee*, a hundred-year old international charity. The initiative goes beyond agriculture to include what Merrin calls the three "life sustaining verticals in Africa: agriculture, energy and healthcare." The idea is to franchise successful agricultural business operation models as they emerge.[172]

On July 31, 2018, the Director General of Israel's Ministry of Economy and Industry, Shai Cohen, signed an agreement with the Jerusalem Office of the Joint Distribution Committee, providing some 3 million dollars for the initiative. This is probably the largest single grant ever provided by Israel's government to support African agricultural work.[173] This is a first, but critical step in what can now be called a "private-public" partnership. Merrin projects initial funding of $500 million over five years, generated largely from Jewish philanthropists, with 90 million dollars in equity and 110 million dollars as standing low-interest loans coming from Israel.[174]

Seed Dissemination: Fair Planet Seeds Ethiopian Experience

One of the most promising initiatives to assist smallholders in Africa is the Israeli-based NGO, *Fair Planet Seeds*. Like many of the most creative civil society endeavors, it reflects the integrity and professional acumen of a highly unique individual: Shoshan Haran. Haran completed a Ph.D. in plant sciences at Hebrew University and continued with a Fulbright post-doctoral fellowship at Rutgers University. Subsequently, she returned to her home in the rural community of Kibbutz Be'eri, taking a lucrative job at the Haz*era* company where

she served for more than a decade as a "senior expert" in the seed research and development unit. When the company was bought by the French group *Limagrain,* the fourth largest seed company in the world, Haran was appointed as head of Limagrain's Genomic Expert Group.

Haran holds great respect for her past employers' contribution to food supply worldwide: "*The seed companies develop the food base for the world. Everything we consume, be you a vegetarian or a meat-eater, relies on the seeds that they develop."*[175] But she also saw that the people who need the high quality seeds most, smallholder farmers in hunger stricken countries, did not have access to them.

In 2011, during a trip with her family to India, Haran had her epiphany moment. She decided to leave her comfortable corporate position and launch a new NGO: *Fair Planet.* Looking back, she describes the decision as coming from the 360-degree perspective her senior management position offered. On the one hand, she appreciated the work that went into developing the technologies that feed the world. But she also saw that the new seed varieties do not reach the world's poorest communities:

"It takes about eight years to develop a new seed variety and between 15 to 20 percent of a seed company's turnover is invested in developing new products." Haran explains. "*These seeds can easily be absorbed in developed markets. In a sophisticated agricultural operation in the developed world, all you have to do is offer a farmer a seed with verifiable benefits and he will start to use them. But the poor smallholder farmers in hungry countries are highly dispersed, many of them are illiterate and do not have access to these seeds. From a moral point of view, I felt like I was required to do something."* The slogan she coined for her new organization was: "*bridging the seed gap".*

The organization's declared mission is "to increase food security and provide new economic opportunities for smallholder farmers in developing countries, through access to high-quality seed varieties and training for improved farming practices."[176] Haran believes that its initial success can be attributed to Israel's historic experience in coping with limited natural resources. *Fair Planet* also enjoys the advantage of an extensive network within the seed industry that Haran had developed.

Perhaps the most impressive factor in the organization's achievements to date is the consortium of leading seed producers that Haran and her team have managed to cobble together to provide seeds to *Fair Planet* for testing their suitability to local, African farming conditions and for training the smallholders. During her time at *Limagrain*, she got to know KeyGene, a private plant-biotech company owned by several seed companies, which serves as a platform for a "pre-competitive research collaboration" focused on *Upstream Technology*. It involves supporting the basic science breakthroughs and conceptual innovations in laboratories which can later be translated by the companies' applied researchers into new and improved types of seeds. This requires stamina: the average upstream phase for developing a new seed innovation will take quite a few years. The ability to rise beyond the usual commercial rivalry and competition for a higher purpose or even for mutual benefit, is virtually unknown in the hi-tech world, but has proven to be a highly effective strategy for a group of major corporations producing seeds around the world.

It was this unique model that sparked the idea to found *Fair Planet* as a "pre-competitive aid collaboration". Haran had the connections to engage senior representatives in these companies and use their proven, pragmatic, collaborative experience to get *Fair Planet* off the ground. Currently, *Fair Planet* partners are comprised of the world's largest seed companies: *Syngenta, Bayer, Limagrain, Enza Zaden* and *East-West Seed*, and its innovative aid-platform is open to all the seed and ag-input companies in the world.

The organization sought seeds that had already been developed that were already working well in relevant climatic areas. In other words, if parts of Ethiopia are similar to Northern Turkey, then seeds that succeeded in Northern Turkey should be tried there. Accordingly, the goal was *not* to develop new seed varieties, but to go with proven ones. She jokes about the results: "We may be only six people on the payroll, with dozens of volunteers, but we have access to about *eighty percent* of the vegetable varieties in the world!"

The organization's initial pilot efforts have been entirely based in Ethiopia, where it quickly gained the cooperative partnership of Haramaya University and the Ethiopian Ministry of Agriculture. Ethiopia also made sense because with 102 million people, it is one of Sub-Saharan Africa's largest countries. It is also one of the few African countries with daily, direct flights to Israel. Vegetable productivity in Ethiopia is also extremely low. At the initiation of Fair Planet activity, in 2012, only one seed company had any Ethiopian presence at all, focusing on large-scale farmers, many of whom were foreigners. The country's enormous community of smallholders -- about 11 million farmers – was simply written off.

The project established training centers in the three main agro-climatic regions of the country and began to systematically evaluate the seed performance of its partner seed companies, eventually identifying the most promising vegetable varieties for increasing farmers' crop productivity. Initial field trials took thirty to forty varieties of each of the main vegetable crops in Ethiopia: tomatoes, onion, hot peppers, and head-cabbage. *Fair Planet's* decision not to focus on staple crops like sorghum and maize was made because of the size of the farms that the organization was targeting. On a small plot, higher return produce like vegetables and fruits, are required for a reasonable return, given the space constraints. Moreover, abundant vegetables tend to improve the collective diet and health of a local community. (Haran points out that the dynamics are similar in Israel, with the larger communal kibbutzim planting staples as opposed to the family farms or "Moshavs", who tend to prefer fruits and vegetables.)

It was at this stage that *Fair Planet's* impressive downstream capacity began to emerge. Haran attributes the success to the unusual talents of the organization's chief agronomist or "technology manager", Dr. Alon Haberfeld. Haberfeld, a former breeder and marketing manager at Hazera, apparently, has a gift. Once the candidate seed types were tested on site in Ethiopia and the most appropriate varieties identified, the organization struck on a training and capacity building strategy which utilizes *lead farmers* from local communities to use winning seed types.

Dr. Shoshan Haran at one of Fair Planet Seeds Testing Site in Ethiopia

The results were breathtaking: for participating farmers, yields immediately increased *fivefold*, along with improved produce quality and marketability. The contrast was dramatic: local varieties of tomatoes may produce 5 fruits per plant; a plant endorsed by *Fair Planet* can provide up to 30 -- and even 50, if farmers takes good agronomic care of their fields. Aggregated, typically Ethiopian vegetable crops average around 8000 kg per hectare of produce a year. The newly introduced seeds generally produced five times that amount.[177] The project is not entirely about yields. Haran is quick to emphasize that the organization evaluates its success according to social indicators as well: How many farmers is it able to lift out of poverty? This approach probably also works well for *Fair Planet's* corporate sponsors. After all, once a farmer moves beyond the poverty cycle, he or she can become a client.

The relationship between the *Fair Planet* staff and the five local representatives of international seed companies with whom it works, is reportedly congenial. After *Fair Planet* selects the most appropriate seeds (often just a handful out of thirty types) the seed company's local agent takes responsibility for registering the seeds for commercial use, a process which can take a full-year.

The organization adopted an interesting tactical orientation for increasing the openness of the farming communities to the new seeds: *Modify as few practices from traditional cultivation techniques as possible.* For instance, the average Ethiopian farmer plows with a bull and uses furrow irrigation. Even though this kind of irrigation may be extremely inefficient, upgrading it is not *Fair Planet's* particular crusade. The organization sees improving seed varieties as paramount. After all, farmers worldwide, are conservative by nature. There is a limit to how much change they would be willing to accept simultaneously.

After seeing the phenomenal success of their neighbors -- who basically substituted the kinds of seeds they were using, with only minimal changes in their production practices -- it

was not difficult to convince other farmers to adopt the new seed varieties. By then, they could benefit from the product profiles that *Fair Planet* generated, designed to address the actual needs of the local farmers. It determines what kind of tomato would be best for a local farmer given the rain patterns, soil acidity, temperatures, -- and any other relevant aspect of the agro-environment. Within just a few years, more than 16,000 Ethiopian smallholders have begun to benefit from the *Fair Planet* program, which frequently enables them to double their annual income in a single season.

Fair Planet's testing and training centers were established near areas where there were already sizable populations and strong demand for agricultural produce (e.g., outside of Addis Ababa). The revenues from sales even during their first season, allow participating farmers to gradually make the critical transition from subsistence farming to an agribusiness mode of operation, just like any farmer in the developed world.

Reaching such a sizable population is possible due to the Israeli and international volunteers who have been mobilized by the organization.[178] The organization looks for young people with an agricultural background (i.e., having grown up on a farm or studied agriculture at a university) who know a little bit about vegetable production, irrigation and fertilization. Of the 130 volunteers thus far, the great majority were Israelis (with five of them from Ethiopian origin, who are delighted to return to their native land as Israeli experts) and five were international.

The volunteers are joined by the local representatives from the Ethiopian Ministry of Agriculture who are formally responsible for providing support in food production for their local communities. Working with the Fair Planet team, they are delighted to bring the new gospel of high quality seeds to local farmers, and coach them in Amharic. Nonetheless, the Fair Planet team tries to visit their "lead farmers", together with the local experts and development agents, at least once a week. The entire model is based on the Israeli experience from the 1950s during Israel's early years, when tens of thousands of refugees were resettled as farmers, most lacking any relevant agricultural experience.

The young volunteers quickly came to function as the program's extension agents, helping local farmers to improve their methods for irrigation, fertilizing and pest control. Techniques, first and foremost, are pragmatic. For instance, the volunteers teach the local farmers how much to fertilize based on easily available tools (i.e., during weeks three through six – use a full bottle cap per plant; during week seven to nine, half a bottle cap is enough). Farmers are shown specifically where in a row they should create a hole for fertilizer application. Because of the higher yields, some new practices are required. For instance, when tomato plants only have five fruits, there is not much maintenance required. When they produce thirty, farmers need to be adept at how and when to tie the plant to support structures. Based on the successful outcomes, the experts and development agents from the Ethiopian Ministry of Agriculture are starting to implement these techniques and extension methodologies and further scale the reach of the program to many more farmers in the projects' regions.

It is worth noting that besides the seeds, the organization does not import any inputs, relying solely on products that are readily available at local stores. Indeed, just like in developed

countries, seeds are the only input given away for free during the first season to farmers, so that they can witness the results with no financial risk. Here, vegetables hold an advantage over trees, as financial returns are immediate. Fruit revenues are delayed.
The economic gain turned out to be extraordinary: Local varieties of tomatoes and hot peppers might reach 7000 kg. per hectare and 2500 kg. per hectare, respectively. When they were replaced by *Fair Planet's* seeds, yields averaged 50,000 kg. per hectare for tomatoes and 35,000 kg. per hectare for hot peppers. Indigenous onions leveled off at 15,000 kg/hectare. *Fair Planet's* seeds can reach more than 80,000. And it is not just a matter of quantity – but also quality: A typical local tomato will last a day and a half before it begins to go bad. The *Fair Planet* alternative offer can have a shelf-life without refrigeration of more than a week.

A recent article in the Ethiopian press, describing the *Fair Planet* initiative, quotes a highly satisfied pilot participant, Fatuma Mohammad: *"I used to produce maize sorghum on rain seasons and breed animals that were not productive; but I contacted Dire Dawa Agriculture Bureau to assist me how I should manage my farm and met my goal. I received quality seed and learned how to develop well-water that transformed my income. Now I had tomatoes and peppers over 900 m^2 of hundreds sustainable plants. Recently, I have supplied my products to the market and collected over 30 thousand Birr; I had more vegetables to sell. I am also planning to produce three times per year."*[179]

Today, the organization is interested in scaling up. Despite its dramatic successes, it has thus far only engaged 16,000 farmers. It hopes that with local communities moving up the learning curve, it will be providing productive high-quality seeds to 50,000 more in the framework of the current project. But reaching Ethiopia's 11 million smallholder farmers will require investing additional resources. *Fair Planet* also seeks to move beyond Ethiopia, with its next target country being Tanzania. With 55 million people and a government that is very interested in cooperating, Tanzania seems like the natural next place to establish a presence. For the organization to make the move and uplift smallholders' vegetable productivity in Tanzania, it needs 800,000 dollars a year for five years.

Amnon Tamir, a former hi-tech executive and the organization's volunteer chair points out that due to the inexpensive African labor market, some 20% of a typical African farmer's expenses are the cost of seeds. (In developed countries, it only comes to 5%.) If this investment is made correctly, it can generate more than enough money for the additional 80% of inputs, including chemicals, fertilizers, irrigation and workers. It would seem that *Fair Planet* is helping make this 20% go as far as it possibly can.

Note of caution
The *Knowledge and Information* initiatives appear to be impressive and promising. Nonetheless, they all suffer from a lack of systematic evaluation studies. Ram Fishman specializes in this branch of social science. Having completed his doctorate with Jeffrey Sachs at the Columbia, Earth Institute, during his subsequent positions at George Washington and now Tel Aviv University he began to assess the effectiveness of agricultural programs and interventions in developing countries. In addition to extensive work in Nepal and India, Fishman has long term studies in place in Uganda, Kenya and Senegal. Fishman urges caution in praising programs that have not been evaluated thoroughly by an objective

third party. With so many development programs declaring success over the years, it would seem that Africa's smallholders would be in a far better place than they presently are.

Part VII: Conclusions and Recommendations

Israel's agricultural experience is unique and is justifiably a source of interest to investors, researchers and farmers alike from around the world. For over seventy years, the country's academic institutions, R&D stations and extension service have produced one of the most sophisticated agricultural sectors in the world. In parallel, in recent years, a start-up culture and entrepreneurial ecosystem that develops agricultural technologies have emerged, making the country a global leader in agrotech. A steady stream of exciting new ideas and ventures have been nurtured by private investment – both local and international. Local scientific acumen and technical creativity holds considerable potential for improving the yields and the wellbeing of smallholders in developing countries.

Yet, it is well to start with a word of humility, and recognition of this potential's limitations. As the senior management in Israel's Ministry of Agriculture emphasizes, notwithstanding the important contributions it makes to international agricultural production, Israel remains a small country. There are constraints, particularly on Israel's ability to disseminate information across the vast continents of Africa and Asia. To be effective, Israeli ventures need local partners and support. Moreover, most Israeli agrotech innovations assume a high level of existing infrastructure and human capacity for implementation. They require aggregation and organization of small individual farmers and creation of larger operational units. Until now, smallholder dynamics have made most new Israeli agricultural technologies irrelevant for this farming sector. Yet, happily, the rural reality in the developing world is quickly evolving.

Mini-grids of electricity, with banks of batteries charged by solar panels can now be connected to homes and farms at a reasonable expense. This new, stand-alone, energy capacity offer communities around the developing world the opportunity to receive constant access to power – independent of national networks.[180] In other words, the new modular infrastructures can create a completely new reality for smallholders, where large irrigation projects, refrigeration and internet associated technologies suddenly are accessible.

At present, Israel's disparate and restless agrotech sector is decidedly not focused on finding solutions for specific problems among smallholders in Africa, India or China. The financial benefits are deemed to be too small and the logistical barriers too great. This is unlikely to change unless economic incentives are provided by philanthropic or public agencies who create both a demand for these products and a safety net for failure by start-ups. Even so, there are numerous Israeli companies and products already available in a range of areas – from drip irrigation and greenhouses to marketing assistance via simple cellphone chat bots – that could make a difference for the lives of agricultural communities across Africa, India and China. Furthermore, Israel's training programs are inexpensive and effective in transferring knowledge and inspiring young farmers from developing countries to be entrepreneurial in their agricultural activities back home. They could easily be expanded.

Most importantly, there is a consensus among university researchers, agrotech entrepreneurs, government officials, teachers of agricultural training programs and investors that Israel can -- and should -- do more to assist the world's small and indigent farmers. With the right incentives, assistance and partners in the developing world, the impact of Israel's agrotech ecosystem and culture of innovation could be magnified far beyond present levels. With world food security an increasingly acute global challenge, this is an opportunity which should not be missed.

Persons Interviewed, 2018

1. Adam Abramson, Hebrew University of Jerusalem / Farmster. Tel Aviv.
2. Tal Argaman, Product Manager, Family Drip Systems, Netafim Corporation.
3. Dan Ariel, Director of Africa Division, Netafim Corporation.
4. Nati Barak, Chief Sustainability Officer, Netafim Corporation, Kibbutz Hatzerim.
5. Shlomo Ben Eliyahu, Director-General, Israel Ministry of Agriculture and Rural Development
6. Talia Ben Niriah, Israel Innovations Authority, Ministry of Economics.
7. Alon Ben-Gal, Senior Researcher, Irrigation Labs, Gilat Research Center, Volcani Institute.
8. Arnon Dag, Soil and Water Center, Gilat Center, Volcani institute.
9. Elazar Fallik, Researcher, Post-Harvest Institute, Volcani Institute.
10. Eli Feinerman, Director of the Volcani Institute, Israel Agricultural Research Organization.
11. Ram Fishman, Department of Public Policy, Tel Aviv University, Ramat Aviv.
12. Gil Haskel, Deputy Director, Israel Foreign Minister, Director of Mashav (Foreign Aid).
13. Shoshan Haran, Director, Fair Planet Seeds, Ashkelon.
14. Moti Harari, Arava R&D Center, Yotvata.
15. Avner Hermoni, past CEO, NaanDan Jain Irrigation.
16. Aliza Inbal, Pears Program for Global Innovation.
17. Nitza Kardish, CEO, Trendlines Incubators.
18. Iri Kassel, Former Factory Manager, Netafim Corporation, Kibbutz Hatzerim.
19. Roy Keagan, Former farm manager, Kibbutz Ketura, Turkana Kenya.
20. Eyal Koret, Principal, Copia Ag and Food.
21. Ran Lati, Researcher, Neveh Ya'ar Research Center, Volcani Institute, Ramat Yishai.
22. Michal Levi, Deputy Director-General for Agricultural Innovation, Chief Scientists Office, Israel Ministry of Agriculture.
23. Ofir Libstein, chair, Agritech Israel Association, CEO, Kibbutz Holit
24. Amnon Lichter – Director, Volcani's Institute for Postharvest and Food Service.
25. Noam Meeri, Director of Institute of Animal Science, Volcani Institute, Rehovoth.
26. Seth Merrin, Founder, "TOV – Tikkun Olam Ventures".
27. Dikla Montekio-Malter, Senior Analyst, Green Soil Investments.
28. Noah Morris, Statistician, Past Farm Manager, Kibbutz Ketura.
29. Jacob Mualem Marom, Director, Kidum, R&D Applications, Volcani Institute.
30. Avi Pearl, Chief Scientist, Israel Ministry of Agriculture
31. Yaakov Peleg, Director, Center for International Agricultural Development Cooperation, (CINADCO) Israel Ministry of Agriculture.
32. Eran Raveh, Soil and Water Center, Volcani Institute.
33. Ezra Robbins, Director, Arava Agricultural R&D Center, Yotava.
34. Netta Robbins, Arava International Center for Agricultural Training, Sappir.
35. Alon Samach. Director of International Program. Faculty of Agriculture, Food and

Environment, Hebrew University Rehovoth.

36. Ido Schechter, CEO, Agrinnovation, Rehovoth.
37. Uri Shani, Chair, NDrip, Past Director Israel Water Authority, Moshav Mazor.
38. Oded Sheseyov, Hebrew University, Faculty of Agriculture, Food and Environment, Rehovoth
39. Jonathan Sierra, CEO, Yarok Technology Transfer, Jerusalem.
40. Matityahu Sperber, Past farm manager at Kibbutz Yahel, Kibbutz Kalia and Kibbutz Beit Ha Arava.
41. Shimon Steinberg, Chief Scientific Officer, BioBee, Sde Eliyahu, Israel.
42. Tamar Weiss, Director of Ag Food-Tech Sector, Startup Nation Central, Tel Aviv.
43. Ron Yariv, Business Development Manager, Amiran Kenya.
44. Hagai Yasur, Researcher in Field Crops, Gilat Campus, Volcani Institute.
45. Uri Yermiyahu, Scientific Director, Negev Highlands Agricultural Research and Development.

References

[1] OECD, *Agricultural Policy Monitoring and Evaluation* 2017, Paris, OECD Publishing, http://dx.doi.org/10.1787/agr_pol-2017-en.

[2]UNCTAB, United Nations Conference on Trade and Development *Trade and Environmental Review*, UN Publications, New York, **2013** http://unctad.org/en/pages/PublicationWebflyer.aspx?publicationid=666.

[3] Cassman, G.; Grassini, P.; Wolf. J.; Tittonell, P.; Hochman, Z. Yield gap analysis with local to global relevance—A review, *Field Crops Research* 143 (1) 2013 4-17.

[4] Food and Agriculture Organization, The *State of Food Insecurity in the World 2015*, 2015**,** http://www.fao.org/3/a-i4646e.pdf.

[5]Black, R. E.; Victora, C.G.; Walker, S.P.; Bhutta, Z.A.; Christian, P.; de Onis, M.; Ezzati, M.; Grantham-McGregor, S.; Katz, J.; Martorell, R.; Uauy, R., Maternal and child undernutrition and overweight in low-income and middle-income countries." *Lancet* 382, No. 9890, 427–451, 2013**,** http://www.thelancet.com/journals/lancet/article/PIIS0140-6736%2813%2960937-X/abstract

[6] United Nations Department of Economics and Social Affairs, World population projected to reach 9.7 billion by 2050, July 29, 2015, http://www.un.org/en/development/desa/news/population/2015-report.html.

[7]Jonathan Rosenthal, Special Report, Technology in Africa, *The Economist*, November 11-17, 2017, 4-5.

[8] John Holmes, Bernie Jones, Brian Heap, Smart Villages, *Science* 350 (6259) 359.

[9] Rosenthal, Jonathan, Special Report, Technology in Africa, *The Economist*, November 11-17, 2017, 10.

[10] Pete Smith, Mark Howden, Thelma Krug, Valérie Masson-Delmotte, Cheikh Mbow, Hans-Otto Pörtner, Andy Reisinger, Josep Canadell and Phillip O'Brien, *Special Report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems (SR2),* Intergovernmental Panel on Climate Change, UNEP/WMO, 2017, https://www.ipcc.ch/report/sr2/pdf/sr2_background_report_final.pdf.

[11] Gil Haskel, Deputy Director, Israel Ministry of Foreign Affairs, interview, Jerusalem, June 11, 2018.

[12] Gerald Andae, More acres put under maize in Galana farm ahead of July launch, *Daily Nation,* June 7, 2017, https://www.standardmedia.co.ke/article/2001228507/third-galana-kulalu-project-harvest-nets-103-000-bags-of-maize

[13] Haskel interview.

[14] Kennedy Kimathi, Private investors to run Galana Kulalu Irrigation Project, *Daily Nation,* January 19, 2018, *D*https://www.nation.co.ke/news/Private-investors-to-run-Galana-Kulalu-Irrigation-project/1056-4269226-10cg0pez/index.html.

[15] Shlomo Ben-Eliyahu, personal interview, August 20, 2018.

[16] Ofir Libstein, chair, Agritech Israel Association, Interview, August 7, 2018.

[17] African Ministers in Israel for First-ever Agricultural Conference, *Jerusalem Post*, December 5, 2016.

[18] Michal Levy, Deputy Director, Ministry of Agriculture, Interview, August 2, 2018.

[19] India, Agricultural Commodities, India Country Commercial Guide, January 8, 2017, https://www.export.gov/article?id=India-Agricultural-Commodities.

[20] Mango Cultivation in India has a Special Israeli Agronomist as a Supporter., *Israel Agri,* April 23, 2017, http://www.israelagri.com/?CategoryID=482&ArticleID=1425.
[21] Haskel, interview.
[22] Haskel interview.
[23] Alon Tal, 2018, "Addressing Desalination's Carbon Footprint: The Israeli Experience", *Water,* 10, 197-210.
[24] Wikistrat, Start-Up Nation Central, *India-Israel: Growing Challenges and Agritech Solutions, 2017.*
[25] Jialing Yu and Jian Wu, 2018, "The Sustainability of Agricultural Development in China: The Agriculture–Environment Nexus", *Sustainability*, 10, 1776; doi:10.3390/su10061776.
[26] J.Y. Lin, 1992, Rural reforms and agricultural growth in China. *American Economics Review*, 82, 34–51.
[27] J. Huang and S. Rozelle, 1996, Technological change: Rediscovering the engine of productivity growth in China's rural economy. Journal of Development Economics49, 337–369.
[28]Alon Tal, 2018, Making Conventional Agriculture Environmentally Friendly: Moving beyond the Glorification of Organic Agriculture and the Demonization of Conventional Agriculture, *Sustainability,* 10 (4) 1078.
[29] Xinhua News Agency, :China-Israel Agriculture Cooperation Under Way", August 13, 2002.
[30] Chinese VP in Israel to Establish Agricultural Cooperation, *Israel Agri* http://www.israelagri.com/?CategoryID=482&ArticleID=1175.
[31] Sharon Udasin, "Israel, China Sign Joint Agricultural Action Plan to Strengthen Cooperation", *The Jerusalem Post,* November 16, 2016, https://www.jpost.com/business-and-innovation/environment/israel-china-sign-joint-agricultural-action-plan-to-strengthen-cooperation-433203.
[32] Reuters Staff, China's Bright Dairy to raise $1.45 bln, buy Tnuva from state-owned parent, *Reuters,* June 9, 2015**,** https://www.reuters.com/article/bright-dairy-china/chinas-bright-dairy-to-raise-1-45-bln-buy-tnuva-from-state-owned-parent-idUSL3N0YV09I20150609.
[33] Eyal Koret, Principal Copia Ag and Food, Interview July 23, 2018.
[34] Shlomo Ben-Eliyahu, personal interview, August 20, 2018.
[35] Matityahu Sperber, Former farm manager Kibbutz Kalia, Yael, Beit Haarava, Interview, August 6, 20189.
[36] Tali Grapes, Website, Last visited, August 2, 2018, https://www.taligrapes.co.il/.
[37] Mehadrin, Growers at Heart, Website, Last visited, August 2, 2018, http://www.mehadrin.co.il/
[38] Dikla Montekio-Malter, Senior Analyst, *Green Soil Investments*, Interview, July 19, 2018.
[39] Roy Keagan, former farm manager, Turkana Kenya, personal Interview, May 4, 2018.
[40] Ron Yariv, Amiran, Kenya, interview, April 30, 2018.
[41] Alon Tal, 2007. To Make a Desert Bloom – The Israeli Agriculture Adventure and the Quest for Sustainability. *Agricultural History*, 81 (2): 228-258.
[42]Alon Tal, *Pollution in a Promised Land – An Environmental History of Israel*, Berkeley, California, University of California Press, 2002.
[43] Yoav Kislev and Haim Tsaban, *Statistical Atlas of Agriculture in Israel*, Beit Dagan, Israel Ministry of Agriculture, 2013.
[44] Eran Feitelson, 1999 "Social Norms, Rationales and Policies: Reframing Farmland Protection in Israel," *Journal of Rural Studies*, 15, 431–446.
[45] Avner De-Shalit, 1995. "From the Political to the Objective: The Dialectics of Zionism and the Environment," *Environmental Politics,* Vol. 4.. 1995 70- 87
[46] Haskel, interview.
[47] Alon Tal, 2008. "Enduring Technological Optimism: Zionism's Environmental Ethic and its Influence on Israel's Environmental History**,"** *The Journal of Environmental History* 13: 275-305
[48]OECD, *Agricultural Policy Monitoring and Evaluation* 2017, Paris, OECD Publishing, http://dx.doi.org/10.1787/agr_pol-2017-en
[49] Ministry of Agriculture and Rural Development, *National Plan for Agriculture and Rural Regions in Israel: Policy and Planning Document*, Beit Dagan, Ministry of Agriculture, June 2013, http://www.moag.gov.il/Files/tochnit_leumit_lahaklaut.pdf.
[50] John Fedler, *Focus on Israel: Israel's Agriculture in the 21s" Century* (Jerusalem: Ministry of Foreign Affairs) 2002.
[51] Israel Export Institute, Israel Agriculture, *Israel Country Commercial Guide,* June, 2017,
[52] Tal, Alon, *The Land is Full: Addressing Overpopulation in Israel*, New Haven, Yale University Press, 2016, 232-236.
[53] Efrat Hadsa, Yoav Gil, 2014, Barriers Preventing Food Security in Israel, 2050, *Managing Global Transitions,*12 (1) 3-22.
[54] Ministry of Agriculture and Rural Development, *National Plan for Agriculture and Rural Regions in Israel: Policy and Planning Document*, Beit Dagan, Ministry of Agriculture, June 2013, p. 10, http://www.moag.gov.il/Files/tochnit_leumit_lahaklaut.pdf.
[55] Jacob Mualem Marom, Director, "Kidum" R&D Applications, August 1, 2018.

[56] OECD, *OECD Review of Agricultural Policies: Israel 2010,* Paris, OECD, 12.
[57] OECD, *OECD Review of Agricultural Policies: Israel 2010,* Paris, OECD.
[58] Israel Association for Ecology and Environmental Sciences, 2016, *Integrating Objectives and Indicators for Sustainable Agricuture in the Framework of Director Support for Agriculture,* (IAEES, Tel Aviv).
[59] Michal Levy, Deputy Director, Ministry of Agriculture, Interview, August 2, 2018.
[60] Uri Tzuk-Bar, Roni Hershkovitz and Yael Kahal, 2015, *Tools for Supporting Agriculture in Israel,* (Beit Dagan, Ministry of Agriculture).
[61] Israel Ministry of Finance, 2018, *Ministry of Agriculture, Main Budget Features* (In Hebrew), http://mof.gov.il/BudgetSite/statebudget/BUDGET2017_2018/MINISTERIESBUDGET/Economy/DocLib/Haklaut_Main.pdf.
[62] Ibid.
[63] Israel Innovation Authority, Startup Division, last visited, August 5, 2018, http://www.matimop.org.il/startup.html
[64] Michal Levy, Deputy Director, Ministry of Agriculture, Interview, August 2, 2018.
[65] Talia Ben Niriah, Israel Innovations Authority, Interview, August 6, 2018
[66] Grand Challenges Israel Competition, Website of the Israel Innovations Authority, Last visited, August 6, 2018, http://www.matimop.org.il/grand_challenges2015.html.
[67] Talia Ben Niriah, Israel Innovations Authority, Interview August 6, 2018
[68] Nitza Kardish, CEO, Trendlines Incubators Israel, Personal Interview, August 21, 2018.
[69]10cg0pez/index.html.
[69] Ofir Libstein, chair, Agritech Israel Association, Interview, August 7, 2018.
[70] Ibid.
[71] Dikla Montekio-Malter,, Senior Analyst, *Green Soil Investments*, Interview, July 19, 2018.
[72] Copia, *Funding Sustainable Technologies,* Website, (last visited, August 3, 2018) http://copia-agro.com/
[73] Eyal Koret, Principal Copia Ag and Food, Interview, July 23, 2018.
[74] Ibid.
[75] Six multinational companies dominate the agricultural input market, *Alexander's Gas and Oil Connections,* June 11, 2011, http://www.gasandoil.com/oilaround/2011/06/six-multinational-companies-dominate-the-agricultural-input-market.
[76] Chief Scientist, Israel Ministry of Agriculture, *Call for Proposals, Nitsan "Noah's Ark – World Microbials for Flora and Fauna,* 2017.
[77] Michal Levy, Deputy Director, Ministry of Agriculture, Interview, August 2, 2018.
[78] Globes Correspondent, Israeli food testing co Yarok wins int'l award, *Globes,* May. 14, 2017, https://en.globes.co.il/en/article-israeli-food-testing-co-yarok-wins-intl-award-1001188394.
[79]Jonathan Sierra, personal interview, Maccabim, July 26, 2018.
[80] Dan Senior and Saul Singer, *Start-up Nation: The Story of Israel's Economic Miracle* (New York, Hatchette Book Group), 2011.
[81] Louisa Burwood-Taylor, CropX Closes Out Series A Round on $10m with New Strategic Investors, *Agfunder*. April 12, 2016, https://agfundernews.com/cropx-closes-out-series-a-round-on-10m-with-new-strategic-investors5677.html.
[82] Oded Shoseyov's Ted Talk Let's not reinvent the wheel, https://www.youtube.com/watch?v=YaLbr8bLE3g.
[83] Tal, Alon, *The Land is Full: Addressing Overpopulation in Israel*, New Haven, Yale University Press, 2016, 232-236.
[84] Alon Tal, 1998. Enforceable Standards to Abate Agricultural Pollution: The Potential of Regulatory Policies in the Israeli Context," *Tel Aviv University Studies in Law,* 14: 223-286.
[85] Rotem Zelingher, 2018, Draft Report, Copy with Author.
[86] Eli Feinerman, Director, Volcani Institute, personal interview, August 1, 2018.
[87] Kidum, R&D Applications and Technology Transfer, website, https://www.agri.gov.il/departments/77.aspx.
[88] Eli Feinerman, Director, Volcani Institute, personal interview, August 1, 2018.
[89] Sad News, Dov Pasternak Passed Away, *Eliminate Poverty Now,* April 18, 2018, https://www.eliminatepovertynow.org/epn-today/2018/4/30/sad-news-dov-pasternak-passed-away
[90] Yaakov Peleg, Director, CINADCO, personal interview, August 20, 2018.
[91] Dr. Avi Pearl, Chief Scientist, Israel Ministry of Agriculture, August 20, 2018.
[92] Yaakov Peleg, Director, CINADCO, personal interview, August 20, 2018.
[93] Dr. Avi Pearl, Chief Scientist, Israel Ministry of Agriculture, August 20, 2018.
[94] Shlomo Ben-Eliyahu, personal interview, August 20, 2018.
[95]Biofishency web-site, last visited August 22, 2018, https://www.biofishency.com/
[96]Eden Shield, website, last visited August 22, 2018, http://eden-shield.com/.
[97] Nitza Kardish, CEO, Trendlines Incubators Israel, Personal Interview, August 21, 2018.
[98] Ezra Robins, personal interview, April 2, 2018.

[99] Dr. Avi Pearl, Chief Scientist, Israel Ministry of Agriculture, August 20, 2018.
[100] Ezra Robbins, Motti Harari, Interviews.
[101] Jacob Mualem Marom, Director, "Kidum" R&D Applications, Interview, August 1, 2018.
[102] Start-up Nation Central, *Agrotech Report 2017,* Tel Aviv, October, 2017.
[103] Start-up Nation Central, *Agrotech Report 2017,* Tel Aviv, October, 2017, 4.
[104] Israel Council for Higher Education, 2016, Statistics Honoring the Opening of the 2016-2017 Academic Year (In Hebrew).
[105] Israel Central Bureau of Statistics, Report on Higher Education, (In Hebrew), last visited, March 20, 2018.
[106] Start-up Nation Central, *Agrotech Report 2017,* Tel Aviv, October, 2017, 7.
[107] Nitza Kardish, CEO, Trendlines Incubators Israel, Personal Interview, August 21, 2018.
[108] Trendlines, *website,* last visited, August 22, 2018, http://trendlines.com/.
[109] Nitza Kardish, CEO, Trendlines Incubators Israel, Personal Interview, August 21, 2018.
[110] Eran Azdan, 2015, Trendline Incubator from Misgav is preparing for its IPO in the Singapore Stock Market at a Value of 80 to 100 million dollars. *The Marker*, July 27, 2015, https://www.themarker.com/technation/1.2693506.
[111] Agrivest, website, last visited, August 22, 2018. https://www.agrivestisrael.com/,
[112] Jacob Mualem Marom, Director, "Kidum" R&D Applications, August 1, 2018.
[113] Nitza Kardish, CEO, Trendlines Incubators Israel, Personal Interview, August 21, 2018.
[114] Jacob Mualem Marom, Director, "Kidum" R&D Applications, August 1, 2018..
[115] Ibid.
[116] For a recent review of the pros and cons of soy diets, with a thorough literature listing see: Harvard School of Public Health, *Straight Talk About Soy*, 2018, https://www.hsph.harvard.edu/nutritionsource/soy/.
[117] Sharon Udassin, Israeli Agricultural Robot Aims to Help Farmers Assess Fruit Yields, *Jerusalem Post*, December 4, 206.
[118] Sharon Udassin, Israeli Firm Launches Solar Powered Device to Monitor Farm Fields, *Jerusalem Post*, December 6, 206.
[119] Tamar Weiss, Start Up Nation Central, personal interview, March 23, 2018.
[120] Eliminate Poverty Now, Dov Pasternak Receives Life Time Achievement Award, July 10, 2017.https://www.eliminatepovertynow.org/epn-today/2017/7/10/dov-pasternak-receives-lifetime-achievement-award.
[121] Homeland Security News Wire, 2017, Identifying, utilizing water resources in Africa drylands, April 17, 2017, http://www.homelandsecuritynewswire.com/srcybersecurity20170417-identifying-utilizing-water-resources-in-africa-drylands.
[122] Aliza Belman Inbal. Shachar Zahavi. *The Rise and. Fall of Israel's. Bilateral Aid. Budget. 1958-2008*, Tel Aviv, Tel Aviv University, Hartog School of. Government and Policy. June, 2009.
[123] Charles Bartlett, 200,. Smallholder market participation: Concepts and evidence from Eastern and Southern Africa. *Food Policy* 33(4), 299–317.
[124]Dr. Avi Pearl, Chief Scientist, Israel Ministry of Agriculture, August 20, 2018.
[125] Moti Harari, personal interview, April 3, 2018, Arava R&D station.

[126] Food and Agricultural Organization, 2008, Chapter 1, Drylands, People and Land Use, in *Water and Cereals in Drylands,* Rome: FAO, www.fao.org/docrep/012/i0372e/i0372e01.pdf.

[127]Asian Development Bank, India Agriculture: Better Irrigation Boosts Rice Yields, March 25, 2013, https://www.adb.org/results/india-agriculture-better-irrigation-boosts-rice-yields.
[128] Prof. Alon Samach. Faculty of Agriculture, Food and Environment, Hebrew University Rehovoth, Interview, March 27, 2018.
[129] Denyse, Tuyishime, Rwanda To Inaugurate Israeli Funded Centre Of Excellence, *KT Press*, February 15, 2017, http://ktpress.rw/2017/02/rwanda-to-inaugurate-israeli-funded-centre-of-excellence/.
[130] Yaakov Peleg, Director, CINADCO, personal interview, August 14, 2018.
[131]Israel Ministry of Agriculture, International Cooperation, CINADCO, last visited, August 14, 2018, http://www.moag.gov.il/yhidotmisrad/CINADCO/Pages/tchum.aspx.
[132] Yaakov Peleg, Director, CINADCO, personal interview, August 14, 2018.
[133] Shlomo Ben-Eliyahu, personal interview, August 20, 2018.
[134] Yaakov Peleg, Director, CINADCO, personal interview, August 14, 2018.
[135] Netta Robbins, personal interview, Arava International Center for Agricultural Training April 4, 2018.
[136] Wikistrat, Start-Up Nation Central, *India-Israel: Growing Challenges and Agritech Solutions, 2017.*
[137] Navit Zumer, Arava herbs as an alternative to Viagra, *Israeli Agri,* January, GET http://www.israelagri.com/?CategoryID=482&ArticleID=1209.
[138] Pesticide Poisoning Claimed 272 Lives of Farmers in Mahrashtra in 4 Years, *Times of India,* 2018, 2018,

https://timesofindia.indiatimes.com/city/mumbai/pesticide-poisoning-claimed-272-lives-of-farmers-in-maharashtra-in-4-years/articleshow/63194105.cms
[139] Avi Hermoni, Interview, Shoresh, Israel, April 26, 2018.
[140] Amnon Bustan Arnon Dag Uri Yermiyahu Ran Erel Eugene PresnovNurit Agam Dilia Kool Joost Iwema Isaac Zipori Alon Ben-Gal, 2016, Fruit load governs transpiration of olive trees, *Tree Physiology*, 36 (3) 1 March 2016, 380–391.
[141] Seth Siegel, *Let There Be Water, Israel's solution for a water starved world,* New York: Saint Martin's Press 2017.
[142] Simcha Blass, *Water in Strife and Action*, Givataim, Masada, 1973, p. 330.
[143] Daniel Hillel, "Irrigated Agriculture," *The Negev, Land, Water and Life in a Desert Environment,* New York, Praeger, 1982, p. 221.
[144] Yuval Azulai, Mexichem completes acquisition of Netafim, *Globes,* February 7, 2018, http://www.globes.co.il/en/article-mexichem-completes-acquisition-of-netafim-1001222740.

[145] Naty Barak, Netafim Offices, Kibbutz Harzerim, Interview April 8, 2018.
[146] *Netafim, Netakit Catalogue*, 2015.
[147] Tal Argaman, Product Manager, Family Drip Systems, Netafim Corporation, personal interview, April 29, 2018.
[148] Netafim, *Community Micro Irrigation*, Tel Aviv, Israel, 2015.
[149] Netafim, *Family Drip Systems*, Power Point Presentation, undated, available with author.
[150] Lonia Friedlander, Alon Tal, Naftali. Lazarovich, 2013 N. Drip Irrigation in Sub-Saharan Africa, Towards a strategy for successful technology transfer, *Agricultural Water Management,*126, 125-132.

[151] Yuval Azulai, Kibbutz Naan sells NaanDanJain Irrigation, *Globes,* May 14, 2012, http://www.globes.co.il/en/article-1000748674.

[152] S. Dabach, U. Shani, N. Lazarovitch, N., 2015. Optimal tensiometer placement for highfrequency subsurface drip irrigation management in heterogeneous soils. *Agricultural Water Management.* 152 91-98.

[153] Daniel Roth-Avnermi, Red Rising, A Message for the Arava: The Pepper Crisis is Over, *Israel Today*, August 10, 2017. http://www.israelhayom.co.il/article/496371.
[154] M.J. Zuidhof, B.L. Schneider, D.R.Korver and F.E. Robinson, Growth, efficiency, and yield of commercial broilers from 1957, 1978, and 2005, *Poultry Science,* 93 (12) 2970-2983.

[155] Food and Agriculture Organization, SAVE FOOD: Global Initiative on Food Loss and Waste Reduction, Rome, 2018, http://www.fao.org/save-food/resources/keyfindings/en/.
[156] Jenny Gustavsson Christel Cederberg Ulf Sonesson, *Global Food Losses and Food Waste*, Rome, FAO, 2011.
[157] World Health Organization, 2017, *Food Safety: Fact Sheet.*
[158] Elazar Fallik, Zoran Ilic, 2014, Grafted vegetables – the influence of rootstock and scion on postharvest quality, *Folia Horticulturae*. 26 (2) 79-90.
[159] Sagi Gal, Sharon Alkalai-Tuvia,Yaacov Pertzelan, Yonatan Elkind, Elazar Fallik Influence of different concentrations of 1-methylcyclopropene and times of exposure on the quality of 'Galia'-type melon harvested at different stages of maturity, *Journal of Horticultural Science & Biotechnology* 2006, 81 (6) 975–982.
[160] Sagi Gal, Sharon Alkalai-Tuvia,Yaacov Pertzelan, Yonatan Elkind, Elazar Fallik, 2008, *Sensory evaluation of 'Galia'-type melons treated with 1-methylcyclopropene after prolonged storage. Journal of Horticultural Science & Biotechnology*, 83 (5) 589–594.
[161] Carmel Produce of Israel, *Commercial Storage Guide for Fruits and Vegetables,* undated poster, Tel Aviv, Agrexco Ltd.
[162] About Stepac, *Corporate Website* 2018, http://www.stepac.com/about-stepac.
[163] Xtend, website last visited, August 12, 2018, http://www.stepac.com/.
[164] Elazar Fallik, Prestorage hot water treatments (immersion, rinsing and brushing), *Postharvest Biology and Technology* 32 , 2004, 125–134.
[165] World Health Organization, 2017, *Food Safety: Fact Sheet.*
[166] How technology can cure market failures in Africa, The Economist, November 19, 2017, https://www.economist.com/news/special-report/21731034-agriculture-information-age-how-technology-can-cure-market-failures-africa.
[167] Adam Abramson, CEO, Farmster, personal interview March 23, 2018.
[168] Adam Abramson, CEO, Farmster, personal interview March 23, 2018.
[169] Ron Yariv, Amiran, Kenya, interview, April 30, 2018.

[170] Ai Beser, Rwandan Orphans Find Hope in Innovative Youth Village, *National Geographic,* November 8, 2017, https://news.nationalgeographic.com/2017/11/agahozo-shalom-youth-village-rwanda-orphans/.
[171] JDC, Government of Israel Sign Partnership Leveraging Israeli AgTech to Aid African Smallholder Farmers, *JDC* , Press Release, July 31, 2018.
http://www.jdc.org/press-releases/jdc-government-of-israel-sign-partnership-leveraging-israeli-agtech-to-aid-african-smallholder-farmers/
[172] Seth Merrin, personal interview, August 1, 2018
[173] JDC, Government of Israel Sign Partnership Leveraging Israeli AgTech to Aid African Smallhjoler Farmers, *EJewish Philanthropy,* August 2018,
https://ejewishphilanthropy.com/jdc-government-of-israel-sign-partnership-leveraging-israeli-agtech-to-aid-african-smallholder-farmers/?utm_source=Aug+2%2C+2018&utm_campaign=Thurs+Aug+2&utm_medium=email.
[174] Sharon Udasin, Bringing Sustainable Development To Africa, Through For-Profit Tikkun Olam, *Jerusalem Post,* May 31, 2017, https://www.jpost.com/Business-and-Innovation/Tech/Bringing-sustainable-development-to-Africa-through-for-profit-tikkun-olam-494398.
[175] Shoshan Haran, Director Fair Planet, Kfar Silver, Interview April 15, 2018.
[176]Dr. Shoshan Haran, personal communication, April 16, 2018.
[177] Mengisteab Teshome, Improving Farm holders' livelihoods, *The Ethiopian Herald,* April 17, 2018.

[178] Abigal Klein Leichman, Sowing seeds of success on Ethiopian farms, I*srael 21C*, December 14, 2015, https://www.israel21c.org/sowing-seeds-of-success-on-ethiopian-farms/.

[179] Mengisteab Teshome, Improving Farm holders' livelihoods, *The Ethiopian Herald,* April 17, 2018.

[180] Empowering Villages, New Ways of Producing and Story Electricity Could be a Boon to Poor People in Rural Communities, *The Economist*, July 14, 59-60.