Reflections on Moving Agricultural Research from Laboratory to Farm

The experiences of researchers at the Industrial Technology Institute, and the Centre for Poverty Analysis, Colombo, Sri Lanka, are drawn on to provide reflections on moving agricultural technologies from laboratory trials to farms in the global South. The challenges and potentials for a hexanal-based Enhanced Freshness Formulation spray and a wrap made from banana fibre (using waste products) are discussed, demonstrating that in generating innovative technologies for sustainable agricultural development, agricultural researchers must think beyond laboratory viability and successful field testing to adaptability in the real world for a range of agriculture stakeholders, and be open to considering the potentials of unexpected, spin-off technologies.

We acknowledge with gratitude the financial support received from the International Development Research Centre (Canada) and the Government of Canada, through the Canadian International Food Security Research Fund. We are indebted to all our international collaborative partners. We also thank E Ruggles for feedback on earlier drafts of this paper.

The authors did not receive any direct financial interest or benefit related to this research.

R S Wilson Wijeratnam (shanthi@iti.lk) and I G N Hewajulige (ilmi@iti.lk) are with the Industrial Technology Institute, Sri Lanka. Karin Fernando (karin@cepa.lk) is with the Centre for Poverty Analysis, Sri Lanka. Elizabeth Finnis (efinnis@uoguelph.ca) and Jayasankar Subramanian (jsubrama@uoguelph.ca) are with the University of Guelph, Canada. M E P Ranmuthugala (madara.ranmuthugala@outlook.com) is with the General Sir John Kotelawala Defence University, Sri Lanka.

Drawing on work done as part of an international, multi-country project on reducing post-harvest fruit losses, this paper provides reflections on the processes by which agricultural technologies for mangoes and bananas developed in a laboratory environment were tested and adapted for use beyond the laboratory. We first discuss the Sri Lankan context and the development of the specific agricultural technologies and then discuss the testing of two technologies in three scenarios: with a large-scale mango producer and linked medium-scale outgrowers; with small-scale mango producers; and with landless labourers working at an agro-industry factory. We demonstrate that in the process of developing innovative agricultural technologies, laboratory-based researchers must think beyond laboratory viability and even successful field testing. In developing technologies that are intended to contribute to longer-term agricultural and economic development and sustainability, it is critical to also consider issues that shape the longer-term realities of technology adoption across a range of agricultural stakeholders and socio-economic levels. Moreover, researchers must be open to considering the potentials of unanticipated spin-off technologies. We hope that sharing our specific experiences will offer insights for academia-based agricultural scientists, particularly those who are embarking on first-time, large, multidisciplinary projects that are geared towards broader issues in agricultural sustainability, livelihoods, and international development.

Project Overview

The work described in this paper is part of a multidisciplinary, multi-country, collaborative project that aims to reduce pre- and post-harvest fruit losses and address food security and farmer economic security, with a focus on the global South. Specifically, we asked how hexanal-based technologies could lessen post-harvest losses of fruit, and, in the process, address economic security and broad food security concerns. Overall project goals included improvements in the shelf life and quality of fruits across the supply chain, enhancing the household economic security of fruit growers, particularly among smaller-scale producers, and broader food security-related goals such as improving consistency in access to quality fruits for consumers. The project, based at the University of Guelph, Canada, involved agricultural and socio-economic research teams in India, Kenya, Sri Lanka, Tanzania, and Trinidad and Tobago, which tested pre- and post-harvest hexanal-based technologies in diverse agricultural, climatic, and cultural contexts, and
with various thick-skinned fruits such as mango, banana, papaya, and citrus fruits. Hexanal is an inhibitor of the activity of phospholipase-D (PLD), a naturally occurring enzyme involved in fruit membrane deterioration by catalysing the hydrolysis of membrane phospholipids (Paliyath and Subramanian 2008; Jincy et al 2017). Applying a synthesised version of the compound delays the ripening processes, but does not otherwise alter biochemical reactions responsible for ripening (Paliyath and Subramanian 2008).

This project builds on an initial two-year project that involved teams in India and Sri Lanka (2012–14). The second phase (2014–18) examines both the feasibility and technical aspects of refining and scaling-up the technologies in the original project locations, in the three new countries, and with diverse fruits. It also looks into the socio-economic realities of how these technologies might (or might not) work for farmers of different scales and for different stakeholders along fruit value chains. These aims required project teams to merge the expertise of agricultural and food scientists with that of social scientists, including researchers with international/community development, anthropology, and agricultural economics backgrounds. While the agricultural scientists worked to develop, assess, and test technologies in diverse locales and with various fruits, the social scientists addressed issues relating to farmer needs, the potential adoptability of technologies for different agricultural sectors, and commercialisation and education possibilities. For the agricultural scientists involved in the project, this often required stepping outside of laboratory-based comfort zones to think beyond technical and experimental successes. The experiences of two agricultural technology researchers from the Industrial Technology Institute (ITI) and a sustainable international development professional at the Centre for Poverty Analysis (CEPA) are the particular focus of this paper. The specifics of our experiences are rooted in the contexts and technologies of this particular project. At the same time, they serve as further food for thought for related work on agriculture, rural livelihoods, and international development.

The Fruit Loss Context in Sri Lanka

Sri Lanka is a significant producer of fruit, including banana and mango. In 2014, total fruit production was approximately 9,16,527 metric tonnes and the Ministry of Agriculture had set a target production of 13,00,000 metric tonnes by 2018 (Presidential Task Force on National Food Production 2016: 20). However, post-harvest losses remain high. For example, an ITI assessment of two Sri Lankan mango value chains, done in collaboration with the Institute of Post-Harvest Technology (IPHT), found fruit losses to be over 30% overall (combining harvest, distribution, wholesale, and retail losses), connected largely to poor stock management practices that resulted in post-harvest disease and rot. This is particularly problematic given that many mango producers in the country are small-scale farmers producing the fruit as a way to supplement other income sources. The combination of post-harvest losses and small farms can contribute to a cycle of limited profits and lack of effective, sustainable, agricultural practices. Similarly, a study of the main banana supply chain in Sri Lanka found losses of around 39%, largely a result of fruit damage and poor packaging techniques (Wasala et al 2014).

Moreover, food security remains a problem in Sri Lanka. Among women and children, malnutrition is higher in estates and rural areas than in urban areas (Jayawardena 2014; Wickramasingha et al 2015), and for rural adults, diets are typically lacking in both calories and protein, with intakes lower for women (Malkanthi et al 2007). Among the 80 sampled farming households in 10 districts, 75% were found to be food insecure (Malkanthi et al 2007). Of course, reducing fruit losses will not solve food security or related malnutrition problems. At the same time, when nutrition levels are low, the wastage of food along the supply chain (in fields, during transport, on shelves)—and the subsequent income and nutritional losses—becomes even more of a concern. These factors demonstrate the importance of finding new approaches to further reduce fruit losses, increase household profits, and improve farming practices. With this in mind, we now offer an overview of the technologies being tested as part of the overall project.

Tested Technologies

A range of hexanal-based technologies have been developed and tested as part of the overall project. These include pre-harvest sprays, a post-harvest dip, a post-harvest vapor treatment, post-harvest biowaxes, electro-spun nanotechnology films, a hexanal-impregnated banana fibre sachet, and a banana fibre-based hexanal-impregnated composite material (for more information on the different technologies see, Cheema et al 2014; Anusuya et al 2016; Jincy et al 2017; Hewajulige et al 2017). One of the most successful approaches has been the use of a hexanal-based Enhanced Freshness Formulation (EFF)
The real test of a technology’s utility is its fit in commercial-scale production trials. Technologies can be promising in a laboratory, but without stakeholder uptake, which is linked to the appropriateness of the technology and the contexts in which the technologies themselves and the socio-economic realities of producers, suppliers, and consumers, which contributes to stakeholder uptake. Therefore, when it comes to farmers and technologies, we need to consider a range of issues, including potential product affordability, labour availability, and short- and long-term goals, as well as subjective perceptions of the value of technologies. Technologies could be more (or less) useful. As such, the team identified three stakeholder groups: a large-scale commercial mango farm partner and associated medium-scale outgrowers; small-scale mango farmers; and a medium-scale banana industry partner that employed landless labourers.

### EFF Spray: Viability and Scale Issues

Over a two-year (four season) period, commercial-scale trials were conducted on between 20 and 30 trees on the farm of the commercial mango partner near Dambulla. The ITI team members carried out the data collection, while the farm’s role was to ensure that EFF sprays were done correctly (after training), and to support the scientists in the field. These trials made it clear that it is relatively easy for a large-scale farm to absorb the EFF spray technology into agricultural practices. In this case, successful testing was not simply about the formulation itself, but also involved pre-existing agricultural practices and access to equipment and labour. Such practices that help optimise fruit yields include regular maintenance and pruning of mango trees, fertilising and watering. Farmers must also be able to monitor fruit development in order to spray at optimal times. The technology requires access to spray equipment and the ability to follow spraying timelines and procedures. Large-scale farms, which employ labourers, can readily adapt their current agricultural management practices and cultivation cycles to include EFF spray costs, equipment and timelines.

It also became clear that a key aspect of the technology optimisation was the timing of the EFF spray. At the commercial farm, individual mangoes are covered in paper bags to reduce insect damage. Therefore, the agricultural scientists believed that spraying before pre-harvest spray. Testing with mangoes in India found that treated trees delay fruit ripening by up to four weeks and increase mango shelf life—particularly in cold storage conditions—by up to 22 days (Anusuya et al 2016). Following successful laboratory-based tests, the Sri Lankan team chose the pre-harvest EFF spray treatment, two bio wax treatments, and the banana fibre-based fruit wrap for fine-tuning and scaling up to field-based trials. For the purposes of this paper, we focus on the pre-harvest EFF spray and the banana fibre-based fruit wrap (see Table 1 (p 37) for applications, results, and potentials). The banana fibre wraps emerged from attempts to develop packing material consisting of coconut or banana-fibre impregnated with hexanal nano-molecules. This idea did not work as planned, but experimentation resulted in the development of a spin-off technology: a biodegradable fruit wrap with the potential to replace the polyethylene sleeves currently used to protect fruits during transportation. Results from simulated transportation and storage trials showed no significant difference between fruits transported with polyethylene sleeves and the banana fibre-based fruit wraps.

These technologies were all deemed viable under laboratory conditions. However, the real test of a technology’s utility is its fit with the socio-economic realities of producers, suppliers, and consumers, which contributes to stakeholder uptake. Technologies can be promising in a laboratory, but without stakeholder uptake, which is linked to the appropriateness of the technology (Park and Ohm 2015), they will have limited long-term sustainability. Therefore, when it comes to farmers and technologies, we need to consider a range of issues, including potential product affordability, labour availability, and short- and long-term goals, as well as subjective perceptions of the value of technologies (Adesina and Baidu-Forsom 1995), farming size and conditions (Fadare et al 2014), social networks and institutional and communications-media environments, including access to knowledge-transfer approaches and/or agricultural extension (Chianu and Tsuji 2004; Lawal-Adewobale and Akeredolu-Ale 2010; Ihm et al 2015; Freeman and Mubichi 2017), and the structural realities of farmers’ lives (Moxley and Lang 2006; Kabunga et al 2011; Sreelata and Antony 2012). In addition, it must be recognised that when it comes to field testing, collecting quality data can take time, requires more than one field season, and comes with logistical challenges ranging from the timeliness of data analysis to ensuring consistency in data collection (Diekmann 2012).

### Laboratory to Farm Realities in Technology Transfer

The overall project placed special emphasis on agricultural livelihoods, particularly for small-scale farmers and in terms of increased opportunities for women. At the same time, it was recognised that some technologies might be better suited to other agricultural stakeholders, including medium- and large-scale farmers, fruit packers, or factories that manufacture value-added products. This required a recognition of the importance of social science approaches when it comes to agriculture (Yatchilla and Bracke 2017) and entailed careful selection of and subsequent close engagement with testing partners who could provide insights, both into the value of the technologies themselves and the contexts in which the technologies could be more (or less) useful. As such, the team identified three stakeholder groups: a large-scale commercial mango farm partner and associated medium-scale outgrowers; small-scale mango farmers; and a medium-scale banana industry partner that employed landless labourers (Table 2).

#### Table 2: Field Testing Partnerships

<table>
<thead>
<tr>
<th>Technologies Tested</th>
<th>Agricultural Stakeholder Details</th>
<th>Partnership Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-harvest EFF spray treatment</td>
<td>Large-scale mango producer and exporter (in operation since late 1970s), Dambulla.</td>
<td>Two-year (four season) test on 20–30 trees. ITI carried out data collection; farm carried out EFF spraying according to ITI’s instructions.</td>
</tr>
<tr>
<td></td>
<td>Over 100 acres under cultivation with proprietary variety of mango (TEJC).</td>
<td>Trials found that fruit performed better if sprayed 3× before harvest.</td>
</tr>
<tr>
<td></td>
<td>2000+ medium-scale outgrowers who produce and sell to the farm.</td>
<td>Training through large-scale mango producer.</td>
</tr>
<tr>
<td></td>
<td>Small-scale, individual farmers (26), between two and 15 trees.</td>
<td>Farmers connected through corporate social responsibility initiative of the mango grower above.</td>
</tr>
<tr>
<td>Banana fibre wrap manufacture</td>
<td>Medium-scale industry partner (banana) employing landless labourers in Udawalawe.</td>
<td>Technology for adding value to fibre extraction introduced by ITI team (fibre processing plant and equipment transfer). Technology transfer demonstrations and commercial-scale production trials.</td>
</tr>
</tbody>
</table>
benefits of the group that can be used to further educate outgrowers about edge transfer channel from the large-scale farmer to this sprayers, and water pumps, as well as paid labour to aid in investing in farming equipment such as tractors, high-pressure crops such as cashews and guava, and were generally able to tween 45 and 1,000 mango trees along with other tree-based scale partner. These outgrowers ranged in size, owning be-outgrowers who then generally sell their products to the large-commercial mango farm partner. In demonstrating the economic networks that were particularly critical, in that farmers may be embedded, in order to most widely recognising both the socio-economic and media networks in transfer, Ihm et al (2015) have pointed to the importance of benefits of a two-stage approach to agricultural information it is in his interest to share knowledge to increase the quality of the fruits available from outgrowers. In this sense, an agricultural development policy environment that provides consistent support to farmers (Chianu and Tsuji 2004).

For small-scale farmers, mango trees are best understood as additional income rather than a primary income source. These farmers tend not to prioritise investing in optimal tree management practices. The labour/time costs of this work are not seen as having a sufficient pay-off. In addition, the spray requires access to equipment, which may not be financially accessible. Thus, while the pre-harvest EFF spray makes sense for farmers who have already invested in optimal tree management practices—particularly if they have clear marketing channels for high-quality fruit—for small-scale farmers, it represents additional labour and financial burdens. In this sense, an EFF spray appears, at this time, to be a less appropriate technology, in that it does not meet the social and economic realities (Park and Ohm 2015) of this group of farmers. It is clear to us that if the EFF spray and its related benefits are to be adopted by smaller-scale mango producers, this needs to be done hand-in-hand with changes to agricultural practices, especially tree maintenance, and through mechanisms that facilitate access to equipment. Essentially, this means farmers would also have to rethink their perspectives on the relative value of mango cultivation, particularly given the small numbers of mango trees owned by this group.

**Banana Fibre Wraps: Viability and Scale Issues**

The project also worked with a banana industry partner, based in Udawalawe, a major banana production region, to introduce a new product—the banana fibre wrap—to the market. The potential benefits of using banana fibre wraps are twofold. First, banana pseudo-stems are a problematic agricultural process, again due to agricultural practices, equipment, and labour. This group of farmers cultivate between two and 15 mango trees, as a minor supplement to other diversified crops grown on a smaller scale, including paddy, onion, corn, sesame, and chilli. Reaching out to this group of farmers is not straightforward, in large part because they work individually and are a scattered group with limited points of coordination. Initially, the project intended to connect with and maintain links with this group of farmers through extension officers attached to the Ministry of Science and Technology. These officers operate throughout the rural parts of the country, providing technical support for rural livelihoods. However, the efficiency and efficacy of extension offers are hampered by financial constraints faced by the respective centres and in the end, it became clear that this was not a viable way to connect with farmers. Instead, the project followed a group of 26 individual small-scale farmers through a corporate social responsibility initiative of the commercial mango partner, who had started a project with the North Central Provincial Council and the Department of Agriculture to promote the cultivation of TJC mangoes among small-scale farmers, with a buyback system. This included the provision of seedlings and training support. While this was a welcome and fruitful alternative, difficulties in connecting with smaller-scale farmers through extension officers demonstrates the importance of an agricultural development policy

The spray … can lengthen the time the fruit can remain on the tree. Bagging to harvesting takes 12 weeks. Assume we got a big harvest of 100 tons. If the demand is 50 tons at that moment, the balance of 50 tons will be wasted [that is, unmarketable]. Planned use of the spray can be used in this instance to hold the fruit on the tree for an additional 4 to 6 weeks.

This demonstrates that optimising the use of new technologies can also involve building on pre-existing, efficient, and, in this case, low-tech approaches to increase the relative effectiveness of both approaches. The trials highlighted the EFF spray’s viability in terms of meeting the commercial interests of a large farm, showing the owner, manager, and workers first-hand the potential benefits.

The large-scale mango partner shares all mango production-related management practices with over 2,000 mango outgrowers who then generally sell their products to the large-scale partner. These outgrowers ranged in size, owning between 45 and 1,000 mango trees along with other tree-based crops such as cashews and guava, and were generally able to invest in farming equipment such as tractors, high-pressure sprayers, and water pumps, as well as paid labour to aid in harvesting. Therefore, there is a pre-existing mango knowledge transfer channel from the large-scale farmer to this group that can be used to further educate outgrowers about the benefits of the EFF spray, while the on-farm trials have allowed outgrowers to see the benefits. Since the large-scale mango farm owner provides a ready market for the outgrowers, it is in his interest to share knowledge to increase the quality of the fruits available from outgrowers. In demonstrating the benefits of a two-stage approach to agricultural information transfer, Ihm et al (2015) have pointed to the importance of recognising both the socio-economic and media networks in which farmers may be embedded, in order to most widely disseminate knowledge. For our field trials, it was the socio-economic networks that were particularly critical, in that outgrowers had a pre-existing and trusted relationship and—perhaps more importantly—a ready buyer for their mangoes in the commercial mango farm partner.

However, adapting to the pre-harvest EFF spray among the smallest-scale mango farmers was a less straightforward
waste product in banana-growing regions of the country. Second, these wraps are compostable, unlike polyethylene sleeves, which are relegated to landfills. In developing banana wraps, researchers were able to address both problems, creating an eco-friendly technology that adds value to an underutilised agricultural waste product.

The banana industry partner already extracted fibre from banana pseudo-stems and technology for adding further value to waste from the fibre extraction process was introduced. Following technology transfer demonstrations, commercial-scale production trials were conducted. Food safety was addressed via the application of a microbial disinfection procedure into the wrap production protocol. The process of transferring this technology was facilitated by the entrepreneurial spirit of the banana industry partner. Since banana cultivation produces a large quantity of unused pseudo-stems, the banana industry partner expressed interest in experimenting with methods of utilising this by-product and invested his own funds and time to establish a processing factory. This kind of partnership, engagement, and investment with new technologies is critical.

During the testing and perfecting of the production system, it became clear that the banana industry partner required assistance with sustaining the business venture, as he was unable to secure a regular market for the banana fibre. We assisted the partner in his efforts to secure a suitable market for the fibre to ensure the sustainability of this industry. As part of securing this market, another technology was introduced to produce rope and twine from banana fibre.

There are clear implications in terms of employment associated with banana fibre wrap and rope production, particularly for highly economically-marginalised individuals. The factory employs four men and seven women, all of whom are primary earners for their families and do not own land for cultivation. Before working in the factory, many had worked in several places as casual labourers or as casual factory workers. The women workers had started working at this factory after they became widows or when their husbands became unable to work or left the family. In general, this group experienced economic instability as part of day-to-day life. Employment at the banana fibre factory, and the consequent daily wages, provided this group with their only stable source of income. This spin-off technology is a good example of how a focus on agricultural development can foster development in agro-processing activities (Christiaensen et al 2011), as long as opportunities are recognised and followed-up.

**Regulatory, Market, and Other Hurdles**

Regulatory clearance, based on laboratory testing and safety data, is an important step before commercialising. Since hexanal-based technologies do not fit clearly into pre-existing agricultural technology classifications—as they are neither...
classified as pesticides nor as growth regulators—hexanal can fall between the cracks of regulation. The process for regulatory clearance was therefore somewhat less clear than it might have been for other agricultural technologies. Ultimately, this was addressed by gaining clearance directly from the Sri Lankan Director General, Department of Agriculture.

However, agricultural scientists working at academic institutions are not always well-positioned to manufacture and market new technologies on a large scale, no matter how promising. As such, it was key that this intellectual property first be patented by the academic researchers and then licensed to a reliable, reputable company for production and distribution. In the case of Sri Lanka, domestic patents were applied for the EFF spray and the technology was licensed to a major agricultural services provider for manufacture and sale. While this means that the spray has the potential to reach a wider audience through an already existing marketing network, we recognise that the team will need to play a role in this marketing. This is particularly important given that costs are always key in the adoption of new agricultural technologies, and that in order to reach small-scale farmers, the EFF spray and its related equipment needs will need to be made available at accessible prices. This is an ongoing process that requires that the laboratory-based scientists step outside of their comfort zone to ensure that all farmers have the potential to make use of these technologies. As Crane (2014) notes, recognising the technical and cultural contexts of research scientists can be critical in agricultural research. For us, this included considering how laboratory-based researchers need to push their skills and training into new realms.3

The banana fibre wrap also has long-term issues, particularly around a sustainable market. While workers at the factory have mastered the production of consistently high quality fibre, paper, and rope, a similarly consistent market for these products is lacking. Currently, the factory continues to operate by relying on the production of banana chips, but the factory owner knows that they will not be able to sustain this for much longer without a consistent market for fibre. This has implications for workers’ sense of well-being and security as, in the absence of a consistent market, the workers know the business is running at a loss and are aware of the lack of long-term job security. We have worked to try and find a consistent market. However, this is a slow-going process. This case highlights the dilemma of an environmentally friendly, technologically successful product that may nevertheless have long-term viability issues.

**Reflections on Lessons Learned**

Although the pre-harvest EFF spray and banana fibre wrap technologies have displayed promising results for reducing fruit losses or adding value to agricultural waste products and creating income opportunities, there are ongoing issues that shape the viability of these technologies. The development of hexanal-based agricultural technologies involved years of laboratory-based work and subsequent trials to move from laboratory to field in diverse cultural contexts. Beyond developing and testing technologies, this has involved ensuring consistent product formulations, paying close attention to food and environmental safety angles of the technologies, and meeting regulatory requirements while also working to minimise processes that can delay commercialisation. In the process, the project has provided practical lessons. For us, one of the key lessons is the recognition that laboratory-based successes do not immediately translate to potential benefits across all farming sectors, even when projects are designed with smaller-scale, economically insecure, farmers in mind. This highlights the importance of the scientific community working in close partnership with the potential end-users of the technologies (for example, large-scale and small-scale farmers, entrepreneurs, and industry partners) and undertaking consultations and tests across these different sectors. It may also involve creative thinking and phased adoption. This point is clearest with the pre-harvest EFF spray, which has definite immediate benefits for large-scale farmers and related medium-scale outgrowers. However, since the spray represents labour, crop management, and financial costs that are currently not viable for small-scale farmers, ongoing work to make the technologies accessible is critical. Working to convert mango farms—even small ones—into better managed farms can also contribute to higher yields and would make EFF more suitable for a range of farmers.

Another important lesson involves being open to unanticipated, spin-off technologies. This is particularly important when considering spin-offs that can be derived at little or no additional cost to the project, which can benefit rural communities by providing livelihood opportunities to more marginal groups, including underemployed women. The banana fibre wrap is an example of this. It is also important to find partners who are willing to try different things and take risks, as is illustrated in the case of the entrepreneurial spirit of the banana fibre wrap partner.

Finally, timeline and funding constraints are important considerations. The timeline for this project was 40 months, preceded by an initial two-year project. The successful development and testing of effective technologies took much of the allotted project time, but regulatory, commercialisation, and marketing realities must also be considered within the life of the project and plans for technology transfer. Moreover, as with any project, there were funding constraints that meant that the agricultural scientists needed to make calculated decisions about which innovations were most promising for potential field testing. These decisions did not always cover every innovation that the scientists wished to pursue. In addition, addressing production and marketing is an ongoing process, with broader considerations for affordability and accessibility across different scales.

When it comes to complex issues, such as post-harvest fruit losses and farmer livelihoods, relying on one technology to solve all problems is a problematic approach. Although a single technology can address different needs, it may not produce results for both smaller-scale farmers and large-scale farmers. It is necessary to consider how different solutions may be best suited to different groups of farmers or how they...
may need to be adapted or integrated with other approaches to meet different needs. This will avoid a single technology being stretched beyond its limits to accommodate the needs of all stakeholders. Preventing food losses requires multiple solutions to address various issues such as extending the seasonality of fruits, extending the storage and shelf life of a commodity, using the excess supply, manufacturing by-products from agricultural waste materials, etc. These can require multiple technological solutions and thus they cannot be approached with a one-size-fits-all mindset. A holistic approach that looks at all angles and issues is needed to address such complex issues.

NOTES
1 Project title: Extension of Harvest Time Using Fruits and Enhanced Preservation of Fruits Using Nanotechnology. Principal Investigator: Jayasankar Subramanian (University of Guelph, Canada). This project was supported by the International Development Research Centre (Canada).
2 At the time of writing, the exchange rate was 158 Sri Lankan Rupees to $1.

REFERENCES


EPW E-books
Select EPW books are now available as e-books in Kindle and iBook (Apple) formats.

The titles are
1. Village Society (ed. SURINDER JODHKA)
2. Environment, Technology and Development (ed. ROHAN D’SOUZA)
   id641419331?mt=11)

Please visit the respective sites for prices of the e-books. More titles will be added gradually.

OCTOBER 12, 2019 VOL LIV NO 41 EPW Economic & Political Weekly