

Extending the Apple Season: Cold Storage in Himachal Pradesh, India



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WPI



Extending the Apple Season: Cold Storage in Himachal Pradesh, India

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Abstract

This project attempted to understand problems affecting fruit and vegetable farmers in Himachal Pradesh, India, and identify ways to alleviate them. To this end, we interviewed farmers, storage facilities, and a local farmers' association, and conducted research into modern preservation practices. Our work indicated that cold storage in the region could be incredibly useful to apple farmers, but awareness and coordination are lacking. To help remedy this, we developed a mobile application and pamphlet helping connect farmers with cold storage.

Executive Summary / Poster



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Extending the Apple Season: Cold Storage in H.P., India

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Indian Institute of Technology Mandi

Apples are Seasonal and Generate Limited Income

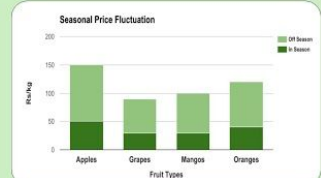


The Regular Apple Season Lasts About 2 Months



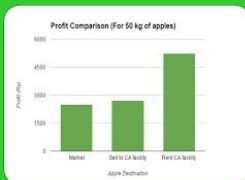
Flooded markets return low profits. Extending the season will spread the supply and encourages higher prices.

EXTENDING THE SEASON WILL INCREASE PROFIT



The differences between in season and off season fruit prices illustrate an untapped economic opportunity.

Fruits have certain harvest seasons, which are represented by the darker colors in the chart above. Extending the shelf life of certain fruits will increase market prices, as shown by the wide lighter colors, especially in the case of apples.



CA storage options for farmers result in more profit from their apples, especially when renting space and selling apples at a later date.

COLD STORAGE IS THE SOLUTION



Cold storage facilities currently exist in H.P. Farmers can take advantage of available space while more facilities are created.

Cold storage, specifically controlled atmosphere storage, can preserve apples for over 6 months. Cold storage is the optimal solution to extend the apple season and produce larger profits.

THE TOOLS FARMERS NEED

Pamphlet for Farmers



Increasing Apple Profit

To increase awareness of cold storage and better apple care

Fruit Growers Association Outreach



Recommendations:

- Pamphlet Distribution
- Encourage farmer collaboration to utilize cold storage
- Conduct workshops with farmers

Ecofrost Micro Cold Storage



eco frost
Battery Free, Solar Powered, 5 Metric Ton Unit

Government Schemes and Subsidies



Recommendations:

- Improve marketing
- Create small farmer compatible facilities
- Conduct workshops with farmers

App for Education and Coordination



Apple care and ways for farmers to communicate

Future Plans

Further success of this project can be achieved in the coming years. Our team has worked diligently to compile the results shown above and in our final report, however we feel that there is still more to accomplish with this project. We believe more impactful results will be accomplished through the efforts of teams that continue our project in the future. Our suggestions to them are as follows: developing our app so that it functions as a communication platform between farmers and cold storage facilities, utilizing an SMS push notification services to communicate with farmers who don't have smart phones, and finally, exploring the possibility of farmer cooperatives so that small farmers can gain access to better equipment and larger cold storage facilities in order to increase profit.

Table of Contents

Abstract	2
Executive Summary \ Poster	3
Table of Contents	4
1. Helping Farmers Preserve Crops in Himachal Pradesh	6
2. Challenges Faced by Himachal Pradesh Farmers	7
2.1 Benefits of Cold Storage	7
3. Methodology	9
3.1 Objective 1: Investigating current practices	9
3.2 Objective 2: Researching and assessing alternative preservation plans	10
3.3 Objective 3: Recommending an alternative preservation plan	11
4. Results and Discussion	11
4.1 Preservation Methods Currently Used by Farmers	11
4.2 Established Methods to Increase Shelf Life	12
4.3 Extending Shelf Life with Cold Storage	12
4.4 Controlled Atmosphere Options Available	13
4.5 Discussion: Missed Opportunity Due to Lack of Communication and Awareness	14
5. Conclusions and Outcomes	15
6. Recommendations	17
6.1 Expand and Improve Cold Storage	17
6.2 Research Micro Cold Storage	17
6.3 Improve Packaging for Crops	18
6.4 Continue App Development	18
6.5 Research Farming Cooperatives	18
6.6 Research More Into Controlled Atmosphere	18
References	19
Acknowledgements	21
Authorship	22
Supplemental Materials	23
Appendix A: Questionnaires	23
Farmer Questionnaire Version 1	23
Fruit Farmers	24
Apple Farmers	25
Market Interviews	26
Cold Storage Owners	26
Appendix B Cold Storage Map	27
Appendix C Pamphlet	28
Appendix D App Screenshots	30
Appendix E Fieldwork Photos	31

1. Helping Farmers Preserve Crops in Himachal Pradesh

Agriculture is a very significant part of the economy in Himachal Pradesh, yet farmers have few means to preserve their crops. According to a 2012-2013 report submitted by the Economics and Statistics Department of Himachal Pradesh, about 69% of workers in the region are employed in agriculture. In addition, 87% of farmers are small-scale (Choudhary, 2016) and own, on average, two acres of land (Singh et al., 1997). With few options in terms of long term storage or preservation of crops, farmers often use relatively ineffective home-constructed storage methods (Overview of grain drying, 2017). As a result, farmers often need to push most of their goods to market immediately, driving prices down and leading to lower profits (Sidhu, 2005, and Bhandari, 2016). Figure 1 demonstrates this vicious cycle.

Our mission was to design and promote a solution empowering farmers in Himachal Pradesh to better preserve their crops, ultimately improving their profit potential. In our research, we analyzed ways we could either help farmers avoid crop damage or increase shelf life, attempting to determine which would benefit farmers more.

Our first objective in achieving this goal was to investigate current food preservation practices in areas near Mandi by interviewing farmers and markets, and determine the problems farmers face. Our second objective was to research and assess alternative preservation plans that would benefit farmers. Our final objective was to select one optimal plan that would maximize farmers' profits, and devise a way for farmers to take advantage of that plan.

Through our research we determined increasing shelf life of crops to be the more potent route for profit increase, while additional ways to avoid crop damage were often difficult or expensive for farmers. Furthermore, we determined that the most accessible, inexpensive, and beneficial way to extend shelf life by several months was through the use of cold storage, an established and growing sector in Himachal Pradesh, potentially yielding huge profit increases for farmers. This solution is merely waiting for farmers to take advantage of it.



Figure 1. The cycle trapping farmers in this region.

2. Challenges Faced by Himachal Pradesh Farmers

Himachal Pradesh is one of the northernmost states of India. In this fairly temperate region, a variety of fruits and nuts are grown (State Department of Horticulture, 2016). The weather in Himachal Pradesh is hot and dry from March to June, rainy during the monsoon season from July until September, and chilly from October to February. According to the Koppen classification system, much of Himachal Pradesh has a “cwa” climate (Grieser, Rubel, Beck, Kottek, & Rudolf, 2006). This is known as a humid subtropical climate, with relatively dry winters and warm summers (Arnfield, 2016).

The region of Himachal Pradesh borders the Himalayas and consists mostly of hills interspersed with river valleys. A case study by Singh et al. in 1997 found that both terraces and paddies dot the region, such as those in Figure 2. Pandey (2009) notes that apple orchards are especially common, with production of apples comprising 88% of fruit production. Farmers tend to rely on a single crop for their income and are unable to keep harvests longer than a few days, so they are at the mercy of the market. The ability to store crops for a longer period of time would allow them instead to take advantage of higher off-season prices and make their produce available throughout more of the year. Since these prices are often **2-3 times** those in-season, low-cost storage could allow farmers to reap immense profits every year. This would also reduce the flooding of markets in-season, raising those prices so farmers without this technology benefit as well.



Figure 2. Terracing style of three farms in Kataula, Himachal Pradesh.

2.1 Benefits of Cold Storage

The climate and geography of this region is conducive to large harvests. The warm weather and rain make the area very suitable for growing fruits and vegetables. The monsoon season brings plentiful rain to needy crops, hastening growth (Arnfield, 2016).

However, these conditions are very poor for storing crops in the open or in makeshift storage. Cold storage, encompassing both standard refrigerated and controlled atmosphere storage, can extend the life of crops a great deal, especially in the case of the ubiquitous apple (Refrigeration, 2015).

While apples left in the open may be lucky to last a week, Fischbacher and Marsden (1966) indicate that refrigerated storage can preserve them up to **six months**, while controlled atmosphere can keep apples for nearly **twelve months**, as demonstrated in Figure 3. Of the many possible methods to store fruit, refrigeration is definitely the most potent, and remains relatively inexpensive. If apple farmers are able to use this technology, they can safeguard their crops from the weather and other dangers, and have more opportunities to sell at market. While there is not a huge selection of cold storage facilities in the region currently, this number is growing due to government subsidies and private investment, and those that exist are attempting to make themselves more accessible to farmers (Bodhi, 2015, Sharma, 2013, and Sally, 2011).



Figure 3. Apples stored in controlled atmosphere storage, still crisp after six months.

Another benefit of controlled atmosphere storage in particular is how well it maintains the quality of fruit. Studies demonstrate that long-term controlled atmosphere storage affects the chemical composition of the apples in a manner very similar to short-term open air storage. In fact, the composition and amount of antioxidants between apples stored in the air and in controlled atmosphere is identical (Van der Sluis et al., 2001). Anthocyanins, a class of flavonoids known help DNA repair and prevent cancer (Lila, 2004), also show no decrease in apples stored in controlled atmosphere (Leja et al., 2003). While the amino acid content of apples may degrade in long term storage, controlled atmosphere storage prevents this due to minimal CO₂ and O₂ levels (Lee & Adel, 2000). Overall, vitamin content is minimally affected by this kind of long-term storage, retaining the nutritional value of the fruit.

3. Methodology

This project was geared toward discovering problems with crop preservation faced by farmers in Himachal Pradesh and ways to alleviate them. Our work attempted to improve their situation and introduce several recommendations for further work. An overview of our project’s strategies can be seen in Figure 4.

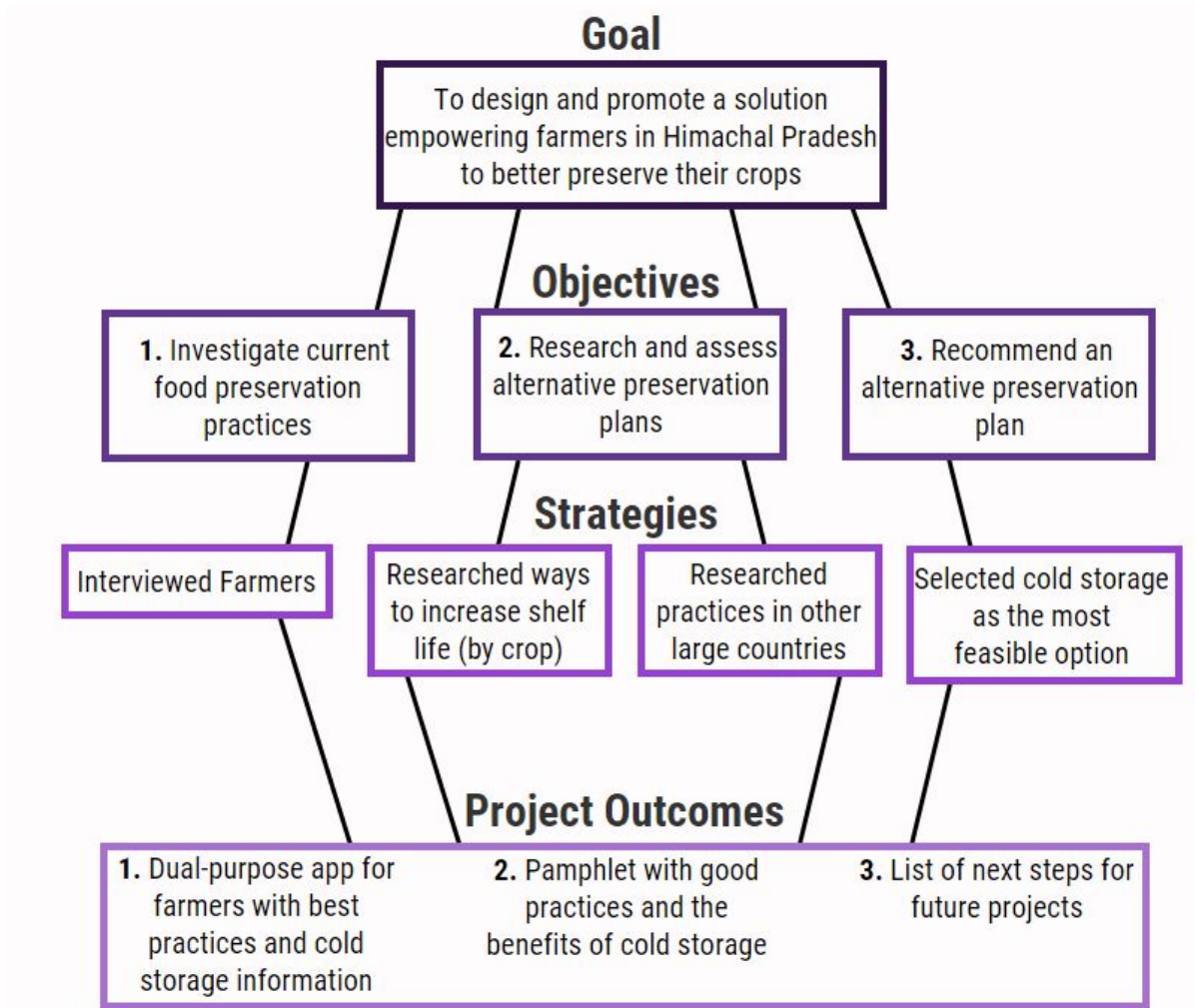


Figure 4. Our project flowchart.

3.1 Objective 1: Investigating current practices

We began by conducting interviews with small-scale fruit and vegetable farmers near the IIT Mandi campus in order to understand what types of problems they face in the **post-harvest handling** or **preservation** of their crops (Appendix A). We interviewed vegetable farmers in Kataula, pomegranate farmers in Bajaura, and mango farmers in Budhar. Finding that there was **not a great opportunity to help** these farmers, we went to apple orchards north of Kullu (see Figure 5). While there, we conducted an interview with the president of the Kullu Fruit Growers’ Association in Patlikuhel to gain insight on problems faced by the apple farmers residing in that region.

Our talk with apple farmers and the Kullu Fruit Growers' Association lead us to the potential benefit of extending the season. To assess this possibility, we interviewed owners of market stalls in Mandi to determine **crop prices** both in- and off-season. This venture indicated to us exactly how profitable selling fruit off-season could be.

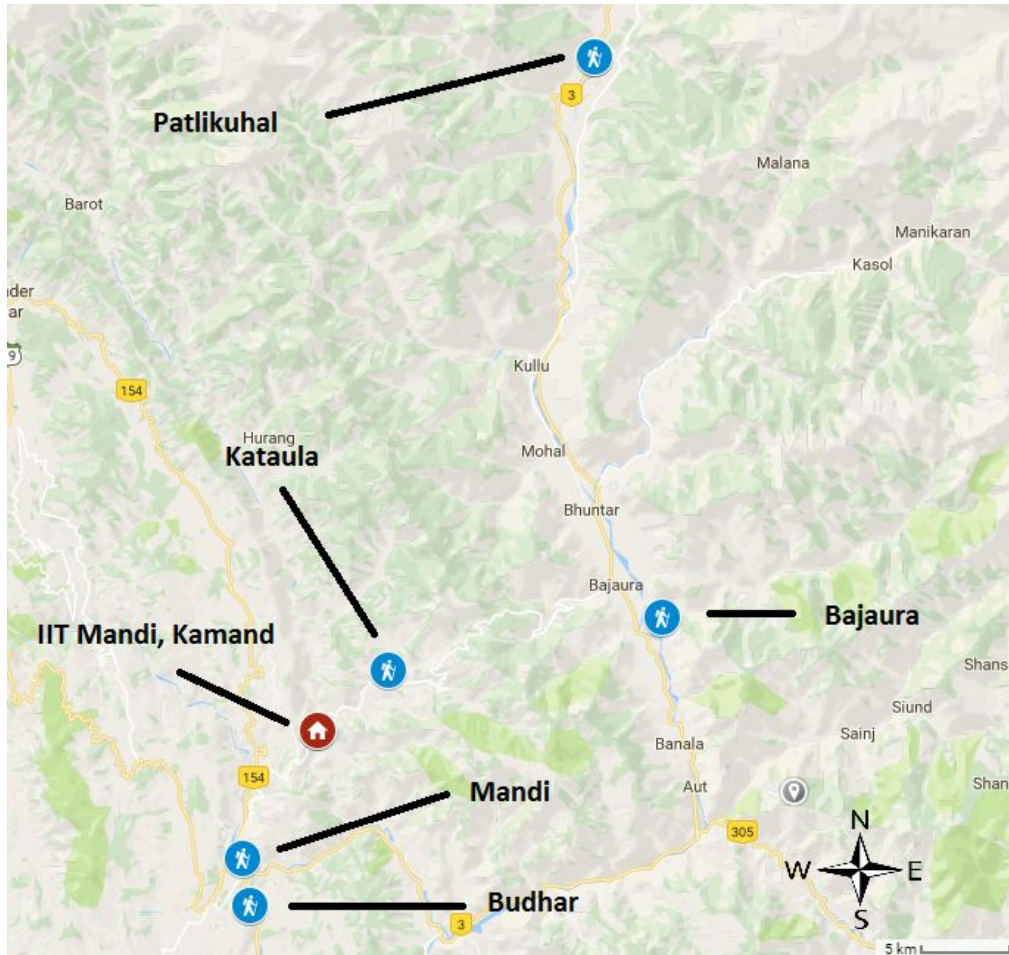


Figure 5. Map of Interview Locations.

3.2 Objective 2: Researching and assessing alternative preservation plans

On campus, we conducted research into many different methods of preserving fruits and vegetables. Chemical treatments, changes in packaging, and water treatment were considered. However, our research into refrigerated storage indicated that it would be by far the best solution. As cold storage is most effective on apples, we performed a cost-benefit analysis on storing the fruit for several months before selling it at market.

Furthermore, we traveled to Patlikuhal, north of Kullu to discover whether or not apple farmers in the area could benefit from **nearby cold storage opportunities**. While there, we talked with owners of Aromatrix Flora Private Limited, a private controlled atmosphere facility, and HPMC Patlikuhal, a government funded controlled atmosphere facility. We ascertained a broad overview of their operation, how fruit or vegetable farmers in the region might benefit from cold storage, and the cost to rent these facilities (see Appendix

A). The talks here indicated strongly that both facilities are willing and able to rent space to farmers, and that they are aware apple farmers would be best served by storing fruit.

3.3 Objective 3: Recommending an alternative preservation plan

In order to craft solid recommendations for farmers, we assessed all the information available to us and identified that cold storage for apples is most effective on the basis of feasibility and cost. We then discussed the merits and flaws of our plan with the Kullu Fruit Growers' Association and cold storage facilities, ascertaining from them how best to combat the lack of awareness and coordination among farmers. Finally, we created a **mobile Android application** and informational **pamphlet** to help **improve communication** between farmers and cold storage facilities, allowing them to use the existing network to their profound advantage. We then brainstormed a number of further steps so others might continue our work.

4. Results and Discussion

The interviews we conducted with fruit farmers helped us identify causes of crop loss and current methods farmers use to extend shelf life. We researched globally used preservation methods, and discussed cold storage at two facilities in Patlikuhal. Information gathered from visiting markets in Mandi allowed us to analyze the costs and benefits of these methods and select cold storage as our optimal plan.

4.1 Preservation Methods Currently Used by Farmers

Both apples and mangoes suffered losses from bruising and rot, while all fruit farmers we interviewed needed to contend with diseases (see Table 1). In order to avoid further loss, every farmer attempted to sell their crops as quickly as possible. In every case, however, these fruits were left outside, under a tarp, or in crates for nearly a day. Most took precautions such as destroying or burying bruised, rotting, or diseased fruit before loading it for transport. Every farmer shipped in cardboard cartons or plastic crates, but relatively few took further packing measures such as using newspaper to line individual fruit or wrap crates. No apple farmer took advantage of any available cold storage.

Table 1. Loss percentages, cited reasons, and time before sale for several types of crops.

Crop	# of Interviews	Loss before Sale	Primary Cited Reasons	Average Wait
Apple	3	15-20%	Bruising, rot, disease	1 day
Mango	3	25%	Bruising, rot, disease, infestation, wild animals	1-2 days
Pomegranate	6	5-10%	Disease	<1 day
Vegetables	2	10%	Rot (unseasonal rain)	12 hours

4.2 Established Methods to Increase Shelf Life

Once we understood the problems faced by farmers, we researched methods scientifically proven to extend shelf life. We considered four main types of techniques: **chemical** treatment methods, **hot water** treatment, improved **packaging**, and **refrigeration**. Of these four, only improved **packaging** and **refrigeration** are economically viable for farmers, and **refrigeration** can extend the life of fruits into the off-season, greatly boosting profits.

Our interviews with produce vendors in Mandi markets indicated major price fluctuations during the year (see Figure 6). If stored for several months, fruit might be sold for anywhere from 2-5 times the original price.

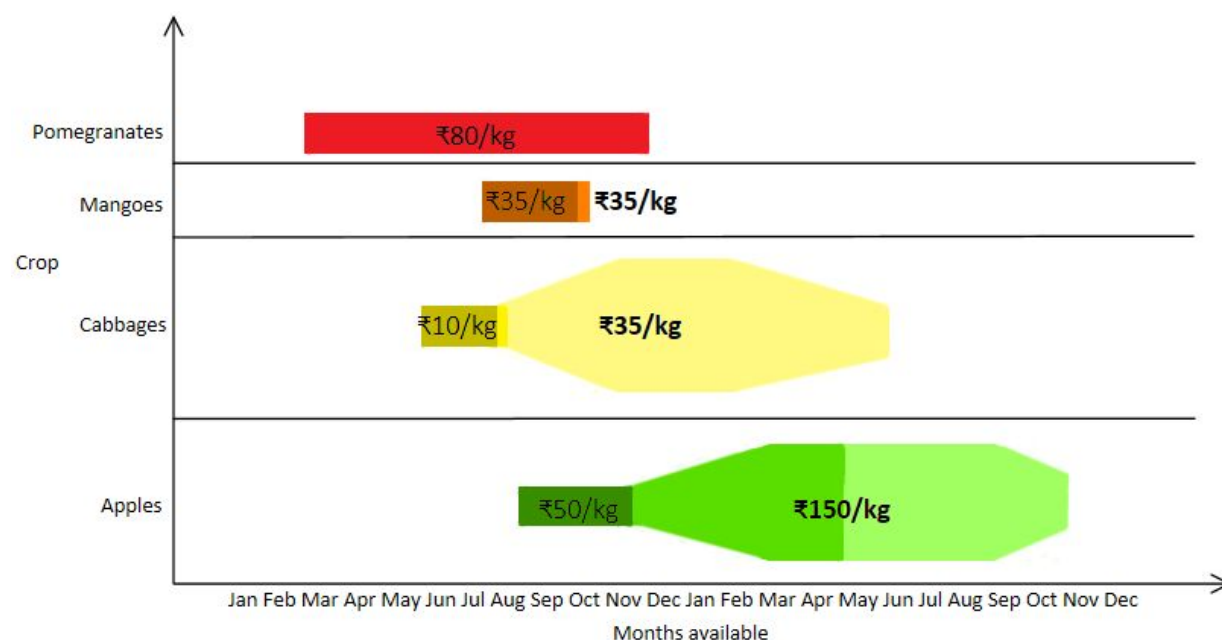


Figure 6. Demonstration of exceptionally long cold storage life of apples (and cabbages) compared to other local fruits. Normal season is shown in darker color, potential from refrigeration in the medium color, and controlled atmosphere life in light color with approximate sale prices. (Only one season shown for clarity)

4.3 Extending Shelf Life with Cold Storage

Our research into refrigeration indicated that of locally grown fruits and vegetables, the storage life of **apples** can be extended up to **six months**, while that of **cabbages** can be extended up to **ten months**. This extends well into the off-season where they can be sold for more (see Table 2). Many other fruits and vegetables do not benefit significantly enough to be sold off-season.

In the case of **cabbages**, however, the vegetable farmers we spoke to all practiced crop rotation to produce income year round, and stated **they would have no time** to keep tabs on stored goods. Furthermore, these farmers grow very small quantities of crops, making storage much less economically viable. Due to these difficulties, we decided that it was not advisable to recommend cold storage for vegetables.

As **88% of fruit and vegetable growers** in this region are apple farmers, there is a massive stakeholder base who can possibly make use of refrigerated storage. Additionally, as seen in Figure 6, apples can be sold for **3 times more** in the off-season, having the potential to significantly increase the income of farmers if stored for just an additional 3-4 months. Furthermore, simple refrigerated storage can provide farmers with more flexibility in selling their crop, allowing them to sell in smaller quantities over a larger span of time rather than selling all at once.

Table 2. Comparison of holding life of several fruits and vegetables. Produce worth refrigerating has the corresponding box highlighted in yellow, and produce worth controlled atmosphere storage has the corresponding box highlighted in green.

Fruit or Vegetable	Apple	Mango	Grape	Pomegranate	Cabbage	Capsicum	Garlic
Shelf Life	<2 weeks	~3 days	3-5 days	6 months	Few days	Few days	3-5 months
Life with refrigeration	3-6 months	1 week	5-10 days		1 week	1-2 weeks	
Life with Controlled Atmosphere	12+ months	6 weeks	5-10 days		10 months	1-2 weeks	
Worth it?	Yes	No	No	No	No	No	No
Notes				No extension with cold	See above	Green keeps the longest	Molds in fridge

4.4 Controlled Atmosphere Options Available

The controlled atmosphere facilities indicated that their space could be rented for just under **2 rupees per kilogram per month**. In lieu of renting space, these facilities purchase apples from individual farmers at **3-4 rupees more per kilogram** than market price, and sell the apples themselves off-season; when purchasing in this fashion, they buy a **minimum of 50 kg** from each farmer so they are able to fill the minimum chamber size of **100 metric tons**. Both these options pose a potential profit for farmers, provided they can bring enough good quality apples that the facility will accept (see Figure 7). Renting space could be as simple as gathering several farmers and making a call to the facility. Transportation could be arranged by the facility or by farmers, but the profit margin is so large that this will hardly make a dent in the farmer's earnings.

Despite extremely low costs for farmers to rent from two controlled atmosphere facilities north of Kullu, none of the apple farmers we interviewed actually stored their crops. When we interviewed staff at these storage facilities, both indicated that they would like to rent out space, but **could not find interested farmers**. Our interview with the Kullu Fruit Growers' Association revealed that farmers have difficulty organizing to rent a large chamber; furthermore, storing the **minimum 150 days (5 months)** that such controlled

atmosphere facilities require poses a financial difficulty for them. We believe the problem lies in a lack of communication between these facilities and farmers, as well as a lack of coordination and awareness among farmers to rent out chambers. Our proposed solutions and recommendations aim to improve these aspects in order to help apple farmers reap the vast benefits cold storage opportunities can provide.

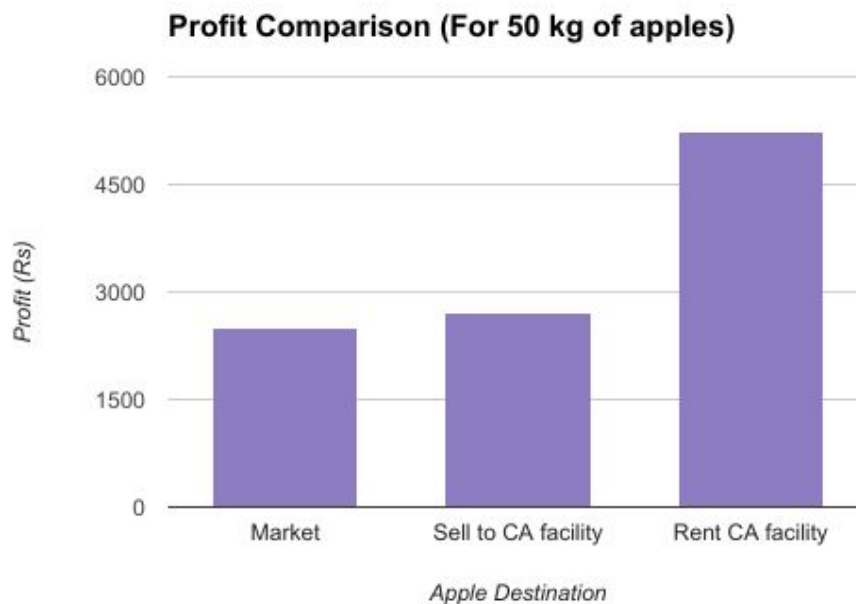


Figure 7. Potential profit for farmers, including rental and transportation costs.

4.5 Discussion: Missed Opportunity Due to Lack of Communication and Awareness

As two controlled atmosphere facilities already exist in the Kullu region, there is an **amazing opportunity available** for farmers. Although the facilities would rather rent, they can also purchase crop from the farmers, paying the farmers up front and using their own transportation. This is a worry free solution for farmers that also gives them an **additional 6-8% profit**. Although the 200 metric ton minimum would be too much for a single farmer, collaborating with others could net them **double the profit**, as seen in Figure 7. Since cold storage facilities have no trouble selling the crop they purchase from farmers currently, there is certainly a market for these off-season apples. Unlike chemical treatments, controlled atmosphere storage does little to change the composition of the apple crop, and retains the nutritional value. Because of all the potential benefits, we believe that enabling farmers to use cold storage is the most effective way to increase their income. The only thing missing is farmers who are both aware of the opportunity and sufficiently organized.

Moreover, the government in Himachal Pradesh is attempting to promote the growth of cold storage across the region. Government subsidies can provide for **75% of the cost of**

cold chain infrastructure, to a maximum of Rs. 10 crore (India Filings, 2014). As a result, private companies are looking to develop further in this region and create facilities more accessible and plentiful for farmers.

Although it is the government's policy to help farmers by spurring the construction of cold storage through subsidies, there appears to be a disconnect between storage and farmers. The government prefers to construct large controlled atmosphere facilities, which can be more difficult for small-scale farmers to make use of. A map of the locations of these facilities can be seen in Appendix B. Small farmers prefer standard refrigerated storage because they are able to access their crops at any time, giving them more opportunities to sell and obtain needed income for survival. Organization among farmers may negate these problems, opening the door to using controlled atmosphere facilities. Since apples survive much longer in CA storage, potential profits also increase a great deal. Increasing accessibility to small farmers and educating them about the options available may lead to an increase in the use of these facilities.

Opportunities for farmers to learn are sparse, however. While the Kullu Fruit Growers' Association indicated they conducted training events and workshops, no one we interviewed knew of any government-run workshops, indicating that they may be insufficiently marketed. If farmers had more opportunity to connect and learn, they could improve their techniques, make use of storage, turn greater profits both in and out of season, and improve their economic situation.

Multiple limitations on our work made it more difficult to draw relevant conclusions. The major limitation has been the language barrier, as farmers and officials alike spoke little English. This barrier has made it difficult to ask the exact questions we wanted, and may have skewed the information we obtained; for instance, we needed to call back the controlled atmosphere facilities multiple times to make clarifications. Moreover, we had many more questions we would have liked to ask both apple farmers and the Kullu Fruit Growers' Association, but were unable to contact them. Without this information, we can only work with the knowledge that many farmers own smartphones, and usually one person in the family can read Hindi, allowing us to use writing to spread information. Once several farmers are aware of the opportunity and the necessity to cooperate, they may begin to spread word of mouth themselves.

Because we gathered data exclusively through interviews, we needed to account for personal bias. Farmers may not have been inclined to be entirely honest with us, fudging numbers to inflate production or downplay losses. In addition, our small sample size, due to time constraints and difficulty in finding farmers willing to interview with us, means our data does not necessarily capture the average fruit or vegetable farmer in Himachal Pradesh. Regardless of these difficulties with our research, we believe all apple farmers across the region could benefit greatly from using cold storage facilities.

5. Conclusions and Outcomes

Cold storage is gradually expanding within Himachal Pradesh, but farmers are still struggling to use the resources at their disposal. Since many farmers are small-scale in nature, our research indicates that they are struggling to profit not only because they have few ways to ensure crops reach market in good condition, but also because they cannot use

methods such as cold storage to their advantage. Several farmers indicated that they were aware that cold storage existed, but that they believed it was of little benefit to them. Moreover, farmers have very few means of communication with each other and potential buyers, including cold storage facilities. In order to rectify the situation, and increase the standard of living for farmers across the Himalayan foothills, better communication channels should be established.

As a first step, we have created a **pamphlet** geared towards informing apple farmers about good practices for handling and packaging the fragile fruit. The pamphlet also contains details of cold storage and its benefits, notably the massively increased profit from each harvest. These pamphlets can be distributed by the Kullu Fruit Growers' Association or the government in addition to their normal workshops, as a guide to farmers (see Appendix C).

Taking the idea a step further, we have built the skeleton of a dual purpose **mobile Android application**, intended for apple farmers. Screenshots of this app can be seen in Appendix D. Part of this app will be **educational**, informing farmers of good agricultural practices and how to handle and care for the fruit. The app also will contain information on cold storage and its benefits, and how farmers can work together to rent large cold storage spaces collectively. The application will also contain a mockup showing how it could be used to allow farmers to **find cold storage facilities nearby**. In this way, multiple farmers who are interested can collaborate and rent a single unit which none of them would have been able to fill individually. If enough interest and support is recognized from these stakeholders in the future, the functionality of this application could be extended to allow farmers to find each other, and allow cold storage facilities to send updates and announcements to farmers, while helping to organize space rental.

Apple farmers and cold storage facilities stand to gain much by using this app to coordinate. Since there is **no shortage** of apple growers in the region, they represent an immense potential market for these facilities, and simply need to work together to rent space. Facilities such as those in Patlikuhel are already available, hoping to rent space to farmers, and the government is providing subsidies to encourage further construction. Storage is cheap, while the **profits are certain to be quite significant**, even if farmers only put a small portion of their crop in storage. Both farmers and facilities are able to arrange transportation, while the facilities can provide crates for farmers to store in. Farmers will also be able to spread the word and inform each other about new opportunities and potential markets to sell to, some of which already exist, purchasing off-season apples from the controlled atmosphere facilities.

Our many interviews indicate that farmers would greatly benefit from **outreach** in addition to current training programs, improving their access to useful knowledge about both caring for and storing crops. Unfortunately, a major obstacle to farmers is their relative lack of funds. The proper way to remedy the situation is to move slowly, step by step, and give farmers the tools they need to improve their livelihoods over time. If farmers were to successfully organize and act as a group (i.e. a **farming cooperative**), they would have greater influence over market prices and better ability to store and sell their crops when it is most beneficial to them. With greater communication and more opportunities to work together, the formation of such farming cooperatives may come to pass. In time, farmers may claim a better place in the economy of Himachal Pradesh.

6. Recommendations

To continue the work we have started here, we recommend **expanding cold storage**, **decreasing crop loss**, and **future projects** in the years to come (see Table 3).

Table 3. Overview of project outcomes and recommendations.

<i>Goals</i>	<i>Increase farmer Awareness</i>	<i>Increase Communication</i>	<i>Increase Accessibility for small farmers</i>
<i>Deliverables</i>	<ul style="list-style-type: none"> · Android Application · Pamphlet 	<ul style="list-style-type: none"> · Android Application 	<ul style="list-style-type: none"> · Android Application
<i>Recommendations for the future</i>	<ul style="list-style-type: none"> · Sign at cold storage · Workshops 	<ul style="list-style-type: none"> · Push SMS notifications 	<ul style="list-style-type: none"> · Farming cooperatives · Expanding cold storage <ul style="list-style-type: none"> · Smaller facilities · Compartmentalization

6.1 Expand and Improve Cold Storage

We would like to encourage both the government of Himachal Pradesh and private companies to attempt to set up relatively small refrigeration facilities. Costs to maintain such smaller facilities will be higher than current larger ones, so work will need to be done in the local community to ensure farmers are aware of them and use them extensively. The primary use of this cold storage will be to allow farmers to reap the benefits of off-season prices. The extra storage space will be another step in bringing fresh fruit to Himachal Pradesh year-round. In addition, when funds become available, refrigerated trucks ought to be gradually phased in to maintain fruit quality. Meanwhile, new and existing storage can look into compartmentalization for greater access to smaller farmers, and ensure they have a sign out front advertising their presence.

6.2 Research Micro Cold Storage

During our research, we discovered a new small-scale refrigeration option co-developed by students at IIT Kharagpur. Ecofrost, a portable, battery-free, solar-powered, 5-metric-ton-capacity cold storage unit offers a multitude of advantages to farmers who invest in it (Pandey, 2011). The unit is delivered and installed by a company called Ecozen Solutions who claim that this Rs. 12.1 lakh system can lead to 40% more profit, breaking even after only 2 years of use. While the price tag may seem like a steep investment to small farmers, government subsidies currently exist allowing farmers to cover 50-70% of the cost using bank loans (India Filings, 2014). Since the device will cover its cost in two years, farmers won't need to risk a large, long-term investment. More research into the logistical aspects of this system is needed in order to make it an easy option for farmers in Himachal Pradesh.

6.3 Improve Packaging for Crops

There are a few cheap methods available to help apple and mango farmers deliver their harvest to market unharmed. Both fruits are easily bruised, even though apples may seem firm; **care should be taken** during harvest and storage not to drop or bounce them around. **Corrugated fiberboard boxes** stuffed with **dry grass or hay** are an effective way to package and transport crops. These materials give a boost to survivability in transport, and have a negligible cost.

6.4 Continue App Development

Further projects might be undertaken at IIT in order to continue our work. Our **app** needs further development and community participation to truly become a useful tool for farmers and storage alike. Both cold storage and farmers should be able to register and find each other. Farmers should also be able to communicate and work together to bring goods to market at better times or store them together to reduce costs. Some obstacles to be overcome include understanding farmers' needs thoroughly and spreading the word to many different villages. As another possibility, a push SMS plan for farmers without smartphones could work to help them coordinate to meet needs. We are aware of at least one established network, *mKisan* (see References), which offers such notifications to farmers.

6.5 Research Farming Cooperatives

A second possible project would be looking into the possibility of forming farming **cooperatives** in this region. Farmers usually work within their families and have wildly varying practices and associates. As a cooperative, farmers have an easier time storing crops, can support each other, and can work together to improve their livelihoods. Overall, the formation of cooperatives would be a major next step for farmers in Himachal Pradesh both financially and socially. Some major problems that need to be overcome are linking enough farmers, generating interest, and distrust and disagreements between farmers. While apple farmers may benefit the most from cooperatives in this way, any group of farmers can work together and improve their conditions.

6.6 Research More Into Controlled Atmosphere

Along with cabbage and apples, there could be more crops that are suitable for controlled atmosphere storage. The crops that we have listed are only ones grown by farmers we interviewed. More research and interviews can be done to see if any other crops can be successfully kept in cold storage.

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Our Website

<https://sites.google.com/site/in17food/>

ISTP Website

<http://www.iitmandi.ac.in/istp/>

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Pamphlet: Created by Virginia Massa. Edited by Peter Melendez, Kunal Shah, and James Muller.

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Supplemental Materials

Appendix A: Questionnaires

Farmer Questionnaire Version 1

1. What crops do you grow here?
2. About how large is your farm?
3. About how much do you produce in a harvest season? (kg)
4. How do you decide it's time to harvest?
5. What method(s) do you use to retrieve the fruit?
6. Do you do anything with newly harvested fruit before storing it? (Such as throwing away bruised/rotting fruit, grading, treatment)
7. What percentage of your crop is lost? What do you believe are causes of loss to your crops after harvest, or in storage?
8. Might we come back and observe your harvest process?
9. How do you store the fruit until transportation arrives? (Is the storage damp or dry? Is it cool or warm?)
10. About how long is the fruit in storage until transportation arrives?
11. How much fruit/crop do you use for yourself, and how much do you sell (in percent of total crop)?
12. How do you bring your goods to the truck and pack them? (I.e. straight into crates, with individual wrapping, boards between each layer of crops, etc.)
13. Do you know the destination of your crops once they are on the truck? (Do you know how long it takes to reach that destination?)
14. Are you aware of any government schemes/plans that may help you as a farmer?
15. (Subjective) Is there anything else regarding the harvest, storage, or transportation of your fruit crops that we may have missed?
16. Our project is working to develop new methods that might reduce loss. Would you be interested?

Fruit Farmers

1. What crops do you grow here?
2. About how large is your farm?
3. About how much do you produce in a harvest season? (kg)
4. Do you do anything with newly harvested fruit before storing it? (Such as throwing away bruised/rotting fruit, grading, treatment)
5. What percentage of your crop is lost? What do you believe are causes of loss to your crops after harvest, or in storage?
6. How do you store the fruit until transportation arrives? (Is the storage damp or dry? Is it cool or warm?)
7. About how long is the fruit in storage until transportation arrives?
8. How much fruit/crop do you use for yourself, and how much do you sell (in percent of total crop)?
9. How do you bring your goods to the truck and pack them? (I.e. straight into crates, with individual wrapping, boards between each layer of crops, etc.)
10. Do you know the destination of your crops once they are on the truck? (Do you know how long it takes to reach that destination?)
 - a. Is there cold storage involved in the process?
11. Are you aware of any government schemes/plans that may help you as a farmer?
12. (Subjective) Is there anything else regarding the harvest, storage, or transportation of your fruit crops that we may have missed?
13. **(If cold storage isn't used)** Are you aware of any cold storage facilities in the area (do you know what cold storage is)?
 - a. (If not) Explain that it is a method that can keep fruit for a very long time
 - b. (If not) Do you think it would be worth waiting to sell your crops in the off-season. Why or why not?
14. Have you considered using cold storage? What influenced your decision?
15. **(If cold storage is used)** How beneficial is it to you?

Apple Farmers

1. What crops do you grow here?
2. About how large is your farm?
3. About how much do you produce in a harvest season? (kg)
4. Do you do anything with newly harvested fruit before storing it? (Such as throwing away bruised/rotting fruit, grading, treatment)
5. What percentage of your crop is lost? What do you believe are causes of loss to your crops after harvest, or in storage?
6. How do you store the fruit until transportation arrives? (Is the storage damp or dry? Is it cool or warm?)
7. About how long is the fruit in storage until transportation arrives?
8. How do you bring your goods to the truck and pack them? (I.e. straight into crates, with individual wrapping, boards between each layer of crops, etc.)
9. Is your crop chilled or refrigerated at any point along the way to your knowledge? (Do you sell very far away?) Why or why not?
10. How much more money do you think your crops would sell for if sold off season? Have you tried to take advantage of this? Why or why not?
11. **(If cold storage isn't used)** Are you aware of any cold storage facilities in the area (do you know what cold storage is)?
 - a. (If not) Explain that it is a method that can keep fruit for a very long time
 - b. (If not) Do you think it would be worth waiting to sell your crops in the off-season. Why or why not?
12. Have you considered using cold storage? What influenced your decision?
13. **(If cold storage is used)** What facility do you bring your crops to?
14. What has been your experience with this facility?
15. (Closing questions) Would you be willing to try cold storage if it is profitable? What obstacles do you anticipate?
16. Are you aware of any government schemes/plans that may help you as a farmer?
17. (Subjective) Is there anything else regarding the harvest, storage, or transportation of your fruit crops that we may have missed?

Market Interviews

1. What produce do you sell here?
2. Where do you get your produce from? Do you have an off-season supplier?
3. What are the prices of your fruits in/off season?
4. Do you work with any cold storage facilities?
5. Does any produce go bad or rot here? If so, how much?
6. What is the cost associated with bringing produce to this market? How do you profit?
7. Do you have any contact information with apple farmers?
8. Where do you sell the produce?
9. How do you receive produce?
10. Do you use any preservation methods here?

Cold Storage Owners

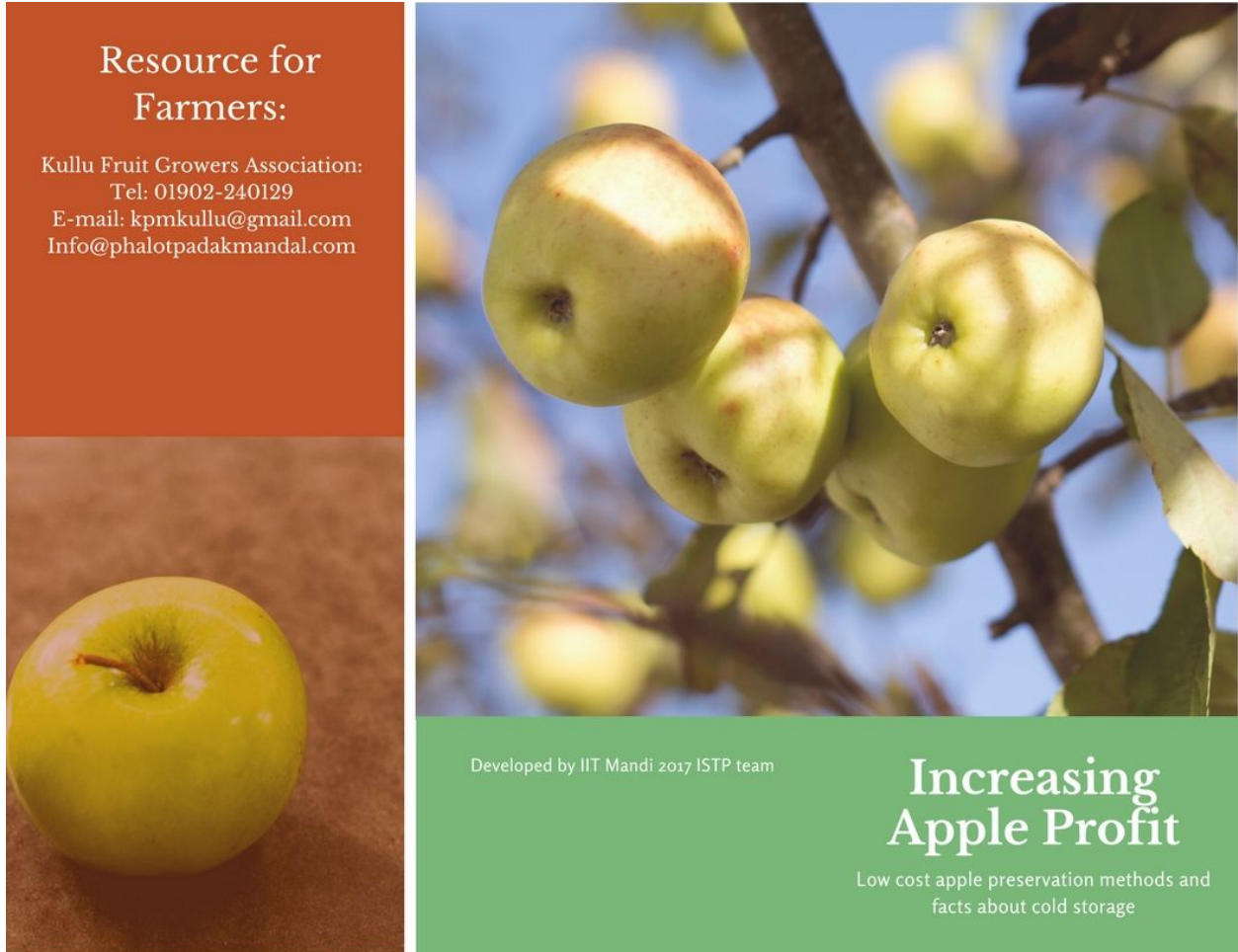
1. Can you tell us your name/role here?
2. How large is this facility?
 - a. How much of this facility is currently in use?
3. What temperatures do you keep your storage at?
4. How long has this facility been operational?
5. What government agencies have a hand in this facility?
6. Who (what kinds of customers) do you rent space to currently?
7. How do you regulate the space? (Such as: restricting when goods are moved in/out, minimum storage amount/duration)
8. How are goods moved to and from the facility? (Can farmers do it themselves? Are companies involved? Reefer trucks? Etc. **Note:** This question is searching for a middleman)
9. Are there any off-season fruits in storage right now? (Such as apples)
10. What are the rates to rent space here?
11. Are you aware of any government subsidies pertaining to cold storage?
12. Do you know of any other cold storage facilities in Himachal Pradesh?
 - a. **(If government facility)** Are all government storage facilities very similar to this one?
 - b. **(If private facility, or previous answer no)** How similar are other facilities to this one?
13. As a worker in a cold storage facility, how do you perceive the demand for facilities like these?

Appendix B Cold Storage Map



Appendix C Pamphlet

Front Page:



**Resource for
Farmers:**

Kullu Fruit Growers Association:
Tel: 01902-240129
E-mail: kpmkullu@gmail.com
Info@phalotpadakmandal.com

Developed by IIT Mandi 2017 ISTP team

Increasing Apple Profit

Low cost apple preservation methods and
facts about cold storage

The pamphlet cover is divided into several sections. On the left, there is a vertical orange bar containing contact information for the Kullu Fruit Growers Association. Below this bar is a photograph of a single green apple on a wooden surface. To the right of the orange bar is a large photograph of several green apples hanging from a tree branch against a blue sky. At the bottom right, there is a green bar containing the title 'Increasing Apple Profit' and a subtitle 'Low cost apple preservation methods and facts about cold storage'. The text 'Developed by IIT Mandi 2017 ISTP team' is located in the bottom left of the green bar.

Back Page:

Best Practices

Apples are typically firm to the touch. Although they seem hard, there is a lot of water in apples causing them to be damaged easily. They should be carefully packed into crates to avoid bruising.



Cold Storage

Cold storage is a way to keep apples fresh for much longer. The cold air prevents the fruit from ripening too quickly, keeping apples fresh for up to 6 months.

Benefits of Cold Storage

Nearly Double the Profit!



Store your crop in cold storage for several months and sell it off-season for significantly more.

Selling to cold storage is also an option. You get an extra 3-4 Rs per kilogram of apples.

How it works

Renting Facilities

- Rental is 15-18 Rs per 20 kg per month
- Farmers are responsible for transportation to and from the facility

Selling to Facility

- The minimum apples bought is 50 kg
- Farmers are paid 3-4 Rs above current market price per kg of apples

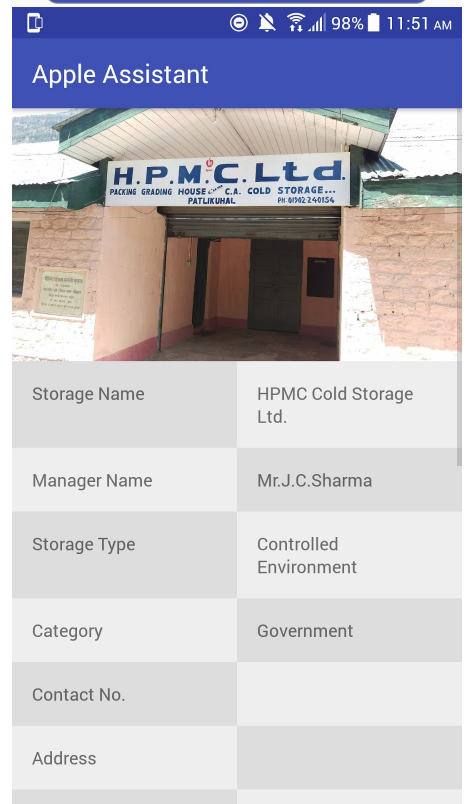
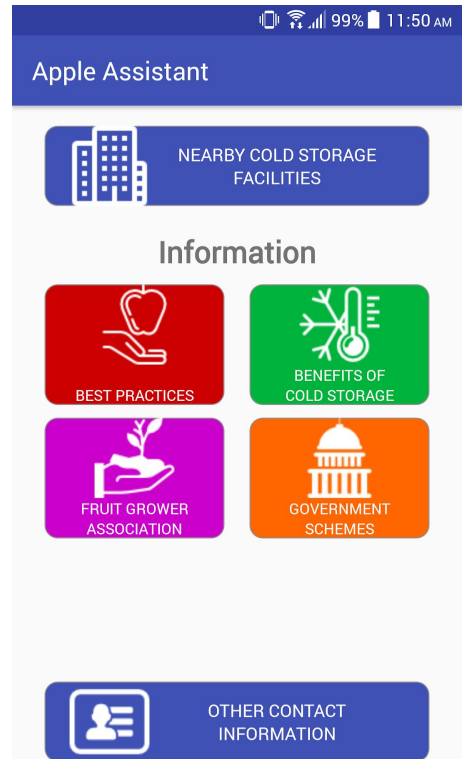
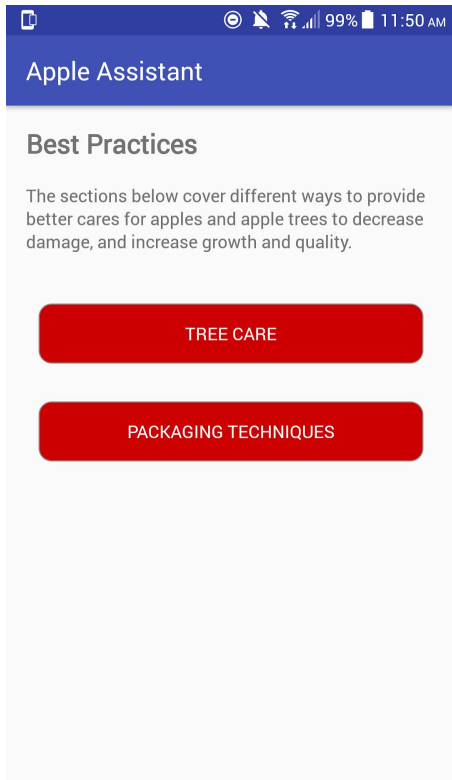
Interested?

Contact:

HPMC Patlikuhul
Mr. Nek Chand
Mobile: 98163-78737



Appendix D App Screenshots



Appendix E Fieldwork Photos

