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REVIEW ARTICLE

PROSPECTS OF VEGETABLE PRODUCTION IN COLD ARID REGION OF LADAKH, ACHIEVEMENT AND FUTURE STRATEGIES

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ABSTRACT

Cold Arid areas are usually confined to high altitudes. Sixteen percent of total land mass is under cold arid zone. Indian cold arid region come under the trans-Himalayan zone. Such regions are confined to Ladakh (J&K), Lahual & Spiti (H.P.) and small pockets in Uttranchal (Niti and Mana Garhwal). Ladakh contitutes 87.4 percent of total cold arid zone of India). It is situated at an elevation of 2550 to 8000m amsl along the valley of river Indus. Intensive sunlight, high evaporation rate, strong winds and fluctuating temperature characterize the general climate. Vegetation is sparse, rains are very rare and most of the land is mountainous desert of rocks, sand & dust. Region has short agriculture season & production of maximum edible biomass is possible only through vegetable cultivation, moreover it plays an important role in balanced diet of human being by providing not only energy rich food but also ensure supply of vital protective nutrients like minerals & vitamins. The region receives abundance sunshine, 300 sunny days per year (2150 kwh per year) even in December the minimum radiation is 4.32 kwh per day. For trapping these natural resources, various types of forcing structures (polyhouse, Ladakhi polyhouse, low tunnel & trench) have been successfully introduced and being popular among the farmers at commercial level also. Vegetable production in Ladakh has great potential, inspite of many restrictions. If the sustainable production of the vegetable to meet the demand of growing population is to be realized then this sector must be given top priority.

INTRODUCTION

Vegetables are considered as 'protective supplementary food" as they contain large quantities of minerals, vitamins and other health promoting phytochemicals, which are required for the normal functioning of the human metabolic processes. Other than this they are also good source of carbohydrate and proteins. Comparatively vegetables are one of the cheapest source of natural nutritive foods. Vegetables crops not only provide nutritional security but are also capable of producing more biomass (5 times the quantities of food per unit area) when compared to cereal crops.The cult of vegenism is increasing in the health conscious world and the nutritional security of underdeveloped and developing countries depend heavily on vegetables. India being predominantly a country of vegetarians, it becomes imperative to attach more significance for the production of vegetable crops. The country being blessed with the unique gift of nature of diverse climate and distinct season, make it possible to grow an array of vegetables. Ladakh is a land abounding in awesome physical features, set in an enormous and spectacular environment. Bounded by two of the world mightest ranges, the Karakoram in the north and the great Himalaya in the south, it is transversed by two other parallel chains, the Ladakh range and the Zanskar range. Cold arid climate is easily distinguished from rest all by cool summer and extremely chilling winter. The climate is readily experienced in Ladakh region of J&K and Lahaul-Spiti, region of Himachal Pradesh i.e. Cold Arid region of India. The cold arid region of J&K is confined to Ladakh province, geographically located between 32°15′ to 36° north latitude and 75°15′ to 80°15′ east longitude. It covers approximately 82605 sq km of which 37,555 sq km is under illegal occupation of Pakistan and China. Hence area with India is 45,110 sq km representing 87.4 per cent of total cold arid region (SKUAST-Leh, 1998).

The salient features of region are:

1. Extremes of temperatures (-40°C in winter and 40°C in summer).
2. Precipitation low (80 mm to 300 mm) mostly in the form of snow.
3. Thin atmosphere due to high altitude so intense solar radiation impregnated with more UV and infrared rays that affect biological material.
4. High speed wind movement.

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5. Altitude of region ranges between 2500 to 8000 metres.
6. Cropping season is of short duration (120-150 days).
7. Only irrigated agriculture is possible.
8. Soils immature, coarse textured and highly permeable.
9. Winter is characteristically devoid of any vegetational greenery.
10. Relative humidity is quite low (20 to 40%).

Climate

The climate of Ladakh is most unusual and extreme in the world. Amidst snowy mountains and beyond the reach of the monsoons that affect most of the India. The Himalaya blocks nearly all the rains from the south, creating a desert in the rain shadow, with most areas receiving only about 100 mm (4 inches) a year. As it is so high and exposed to winds blasting from central Asia the winters are long and bitterly cold with mild summer. In fact, the Dras region lays some claim to being the second coldest non-polar place on earth with temperature reaching -45^{o}C. Since the region lies in the rain shadow, it is one of the driest places on earth. Under such harsh circumstances agriculture is difficult. Nevertheless, by diverting glacial fed rivers into stone built terraces, gathering soil through sedimentation, enriching the soil with organic manure and other practices, the local people are able to cultivate staples.

Altitude and agriculture

Considerably altitude variation occurs in areas of cold arid region which have been brought under agriculture management by human being. The altitude of arable lands begins from 8,500 ft amsl in Kargil area to 14,000 ft. amsl in Kardung and Rumtse areas in Leh district. Due to altitude variation, the length of cropping season, type of crops and cropping pattern vary in cold arid region. Considering the scope of crop production in Ladakh, whole arable land has been zonalised into three parts, upper, central and lower on the basis of altitude.

Soils

The soils of Ladakh are poor in fertility. The soils varies from gravely, sandy, sandy loam, silty, clay loam to clayey. The soils have usually low water holding capacity with a pH ranging from 7.4 to 9.6 in Leh while in Kargil it ranges between 7.7 to 8.2. Salinity is a problem in certain patches. All cultivable zones of Ladakh are good for vegetable production.

Agriculture in Ladakh (A brief outlook)

Despite the incredible restriction of an eight month winter (thus a four month growing season), virtually no effective rain and a land providing few resources, Ladakhis have traditionally provided more than their needs in all but a few commodities. Largely a self sufficient agrarian economy, it was extraordinarily complete in the range and quantity of goods produced. Evolved over centuries, Ladakhi agriculture is inseparable from the social structure of the villages and the credos of Buddhism. Central to the agriculture is the harvest for irrigation of summer snow melt from the high mountain. Channels, often many kilometres long, ferry the water to the villages where a finely tuned system of small channels and equally finely tuned social system of determining who gets water when, direct the water to fields. The fields are mostly terraced, built with elegant stone walls, and most skilfully arranged. Each in tiny, the very antithesis of broad scale agriculture, yet they produced higher yields. Land holdings are only one to two hectares, but easily sufficient. The different crops grown in the region are barley, wheat, peas, vegetables and mustard, and the iridescent green of the fields in the summer is in remarkable contrast to the bare hills around.

Nothing is wasted in Ladakh, animal dung becomes fuel, human waste goes to the fields (the traditional Ladakhi toilet in an efficient composting design), even old gonchas (traditional dress), the all purpose wool cloak, may be used to patch irrigation channels. The scattered and meagre wild

Table 1. Altitude and period of cropping season in some important places of Ladakh region

Place	Altitude (ft ASL)	Period of cropping season
Chyshul	13,000	April to September
Digger	13,800	April to September
Diskit	9,500	April to august to September (1st week)
Drass	10,000	May to September
Durbuk	14,400	May to September
Gya	13,900	April to September
Kargil (main area)	8,700	March to July to September
Khaltse	9,500	April to September
Khardung	14,000	May to September
Leh (Thiksey, Stakna)	11,700	May to September
Loma	13,500	May to September
Matho	12,200	May to September
Nimmo	10,000	April to September (2nd week)
Nyoma (Changthang)	12,800	April to September
Padum (Zangskar)	10,500	April to September
Panamic	9,800	April to August to September
Rumtse	14,000	April to September
Saspol	9,700	March to August to September
Spituk	10,500	May to September
Suru valley	11,000	April to August
Tangyar	13,500	April to September
Timasgam	11,000	April to August
Turtuk	8,500	March to July to September

[Source : Sharma, 2000]

Table 2. Percentage analysis of soil in cold dry arid Zone of Ladakh

Place	Coarse	Fine sand	Silt	clay	Textural class
Dras	0.88	19.82	53.90	25.00	Silt clay
Kargil	6.44	61.10	3.30	20.50	Loamy clay
Leh	4.17	24.83	2.50	8.50	Loamy sand
Suru	1.00	58.55	28.50	12.00	Loam
Zanskar	3.77	34.83	15.00	25.50	Sandy clay

Table 3. Area (ha) under vegetables in Leh and Kargil district

	Year	Leh	Kargil
1.	2001-02	240	211
2.	2002-03	246	211
3.	2003-04	245	329
4.	2004-05	299	220
5.	2005-06	310	317
6.	2006-07	310	216

[Source : Department of Agriculture, Leh & Kargil, 2008]

plants, too are used for fuel and fodder. Social relations are based on sharing of labour, tools and animals to a remarkable degree. The cooperation is formalised in various ways; shared agricultural work, such as neighbours combining to harvest each of their crop in turn, as does the practice of collectively taking animals to high pastures. The distribution of water is determined by a time honoured system overseen by people on a rotational basis.

PRESENT SCENARIO

Vegetable production scenario in the region has undergone a sea change against the one prevailing before nineties. From need driven to market driven, Ladakh has come a long way. Today total area under vegetables in Leh district is 310 ha with the production of 75440 q and in Kargil district it is 216 ha with a production of 49777 q. this gives the total production of 125217 q. Average productivity of vegetables is 124.7 q/ha. Malnutrition was not uncommon in Ladakh, but was the other way round. Malnutrition existed not as an underperformance of the body but as a way of life. They hardly knew the importance of nutrition and vegetables were a rare item of their diet. But now people becoming more educated, advanced and aware, nutrition is a major issue for them today and are conscious of the fact that vegetables are the major source through which the so called nutrition could be met out. Thus the past few years have seen people adopting various measures for increasing their production as well as to meet the ever increasing demand. With increase in frequency of movements of Ladakhis in and out of the region particularly for education of the youngsters and other winter movements, there has been a change in taste and food habits of the people thus pressurizing on more variety in diet especially vegetables. This has also led to introduction of various types which until now were not grown. About more than a lakh tourists visit Ladakh every year having different tastes and food habits and as such demand more in variety as well as in quantity. So there is an immense pressure on production. Today almost every family in Ladakh has one or two of its members earning in government jobs or through tourists. With government performing economically better and increased influx of tourists the purchasing power of people have definitely increased and as such demand for variety and quantity. Various vegetables and their varieties which can be successfully cultivated are:

Group	Vegetable	Suitable varieties
Cole crops	Cabbage	Golden Acre, Pusa Drum Head, Pride of India, Mitra
	Cauliflower	Pusa Snowball, Snowball-16, Early Snowball.
	Knol Khol	White Vienna, Purple Vienna,
	Broccoli	King of market
	Kale	Italian Green Sprouting Khanyari/Kawdari
Root crops	Radish	Pusa Himani, Scarlet Globe
	Turnip	and Local ,
	Carrot	PTWG, Nageen
	Beet root	Nantes, Local, Yamdagni, Chaman Detroit Dark Red
Leafy vegetables	Beet leaf	K Raya, FRL Sel
	Spinach	Prickly Seeded
	Karam Saag	Kashmiri
	Fenugreek	Pusa Early Bunching, Kasuri
	Coriander	PD-1, Pant Haritima
Leguminous crops	Pea	Bonnevillae, Arkel, Lincoln, FRL Sel, Azad P-1
	French Bean	Contender, Anupam
Bulb crops	Onion	Local White, Red coral, Agrifound dark Red
	Garlic	---
Salad crops	Celery	Early Zem
	Lettuce	Great lake , Dum(local)
Tuber crops	Potato	Kufri Chandramukhi, PP-2500, PP-48, MF-1/TPS-67,, MF-1/TPS-3, MF-II/TPS-67, MF-II/13, TPS FRL-1 (OP) , TPS FRL-2(OP)
Solanaceous fruit crops	Tomato	Pusa Ruby**,** Sioux, Marglobe, Rupali, Punjab Chauhare**,** **Pusa** Sheetal, Darl hybrid,
	Brinjal	FRLSel-1**, 2, 7**.
	Capsicum	
	Chilli	PPR, PPL California Wonder, HC-202, Nishat-1 Pusa Jawala

(Source: Singh et al., 2000)

These above conditions have brought a sea change in vegetable market today. From a neglected sector to the status of a cash crop, vegetable production has come a long way.

ACHIEVEMENTS

1. Identification of about 60 types of vegetables and their improved varieties for cultivation and standardization of their agro-techniques by DIHAR, Leh. By adopting these techniques, local farmers are able to supply above 45 per cent requirement of vegetables of troops locally and thereby reducing the transportation cost by air @ Rs. 22/kg, besides improving their economic condition.
2. New vegetable crops such as Parsley, celery, Japanese bunching onion, sweet turnip, garlic, karam sag were introduced and the cultivation practices is standardized by DIHAR but their cultivation on commercial scale is still in an infancy stage.
3. True potato seed (TPS) technology: This technology has been perfected for production of quality seeds of potatoes in high altitude areas. The technology has benefited local farmers who earlier used to procure potato seeds from other states.
4. Storage of vegetables is an important aspect of vegetable production in the cold arid region. Fresh vegetables are to be protected against extreme arid conditions. DIHAR has developed underground storage techniques for storage of vegetables during winter. As fresh vegetables during winter, shall undergo freezing during night and thawing during day resulting in their spoilage. In this way a large quantity of vegetables can be stored to meet the local requirement to some extent during the cut off period.
5. DIHAR has designed and developed low cost drier such as solar polyhouse drier, tunnel drier LPG driers, for scientific dehydration of surplus vegetables of the region.
6. Cucurbits in cold arid – use of plastic mulch made it possible to grow cucurbits in open field of cold desert of Ladakh, which was hitherto considered impossible. Protected cultivation of vegetables in general and use of plastic mulch in particular are important technologies for sustainable vegetable farming in cold desert.

CONSTRAINTS

The land based economy is in a general state of decline in entire Ladakh region today. Problems are of both agricultural

and non-agricultural ranging from administrative policy to research. People are leaving the sector in droves, and things have come to such a pass that there is now a shortage of local workers in the village during the agricultural season. There deserve immediate redressal if the region is to be made self reliant. Important among than are enumerated below:

1. Agro-climatic constraints

Cold arid agro-ecosystems are not much stable, mainly because of fluctuating environments. Of all temperature and moisture are the two parameters which limit cropping season period for 4 to 5 months only, and all the agri-horticultural activities are confined to these period only. Due to these reason Ladakh experiences acute shortage of vegetable during winter. Evidently pulses take the lead in daily diet forcibly.

2. Lack of high yielding varieties

Several vegetables can be grown successfully in cold arid region. Unfortunately high yielding varieties have not been developed in many of them especially for cold arid, agro-climate except in some field crops. Due to unstable climate, development of promising varieties needs long term testing. This fact doesn't match with the present 2 year service and transfer policy of government for cold arid region. Whereas something has been done in field crops, more is required in vegetables, particularly in non-traditional vegetables such as tomato, brinjal, capsicum, lady's finger and cucurbits. Even within cold arid region, agro-climates vary considerably with altitude (Sharma and Mir, 1997) and indicate the scope of zone specific varietal development programmes.

3. Hurdles in transfer of technology

Cold arid region is wide spread and is the biggest region in the state of Jammu and Kashmir, separated into different valleys by inaccessible mountain ranges. The valleys are not easily approachable and may remain cut off from each other many times during a year. Means of transportation and communication are poor. This hinders the process of transfer of technology and the areas tend to remain backward in aspect of technology, information and other necessity infrastructure. Thus bringing such areas under modern agriculture is quite difficult.

4. People's lack of interest

Most Ladakhis today are disinclined towards working in the fields. The many new avenues of employment that have become available to Ladakhis in the recent years (army, government, tourism etc.) have made the prospect of working in the land based economy less inviting. The main drawbacks that are provide by the people with respect to the agriculture are: a) It requires hard physical work which is often not compensated by adequate returns, and b) It is not remunerative in its current state and barely takes care of subsistence level needs. However, what most fail to see is that the profusion of options available to them today (buoyed by which they look upon the land based occupations with disdain) may not always remain. Jobs in army may, reduce drastically if relations between India and its neighbour improve.

5. Lack of technical know how

Ladakhi farmers are still following the age old practices of production. They lack adequate information and proper guiding. The region is dominated by a Buddhist community who strongly believe, trust and respect their traditional practices and customs. Many aspect of agricultural production and management are governed by religious beliefs. Sowing, weeding, harvesting are often undertaken at a particular time as determined by community or monestry. This affects the rate or adoption of modern practices by farmers.

7. Lack of quality planting materials

Quality seed is the basic input for achieving higher production. Present infrastructure is insufficient for supplying true to type seeds of vegetable crops. The seed produced or procured by department of agriculture and sold to the farmers are insufficient to fulfil their demands and farmers have no way except to purchase the seed from other sources which are not generally true to type and high yielders.

8. Insufficient technical manpower

All departments in general and agriculture in particular, are contributing for below the expectation in progress of cold arid region for want of scientific and technical staff. Due to unpleasant climates remoteness and uneasy accessibility round the year, one is reluctant to serve there. Many a times it is a punishment posting. Constraints are several, severe and of syndromic nature while staff mostly posted is fresh, unexperienced and incompetent to tackle the situation.

9. Lack of post harvest technology

Ladakh faces severe shortage of vegetables during winter. A proper post harvest technology is the biggest need of the hour, lack of this technology would never let Ladakh attain a self sufficient status.

10. Lack of genuine price for the farmer

The local produce doesn't get good price compared to those imported from plains which plays a great role in discouraging the local farmers.

11. Depleting natural resources

The natural resources that support that cultivation of vegetables and other agricultural commodities are themselves deteriorating rapidly in Ladakh. Soil erosion is widespread phenomenon in the region, because of large temperature fluctuation, causing freezing and thawing of soils, steep and long mountain slopes enormous runoff build off due to quick glacier and snow melt and existence of highly erodible soils. Similarly, water resources too (especially glaciers) have been receding for the past many years, purportedly due to the effect of global warming.

STRATEGIES

If the sustainable production of the vegetables, to meet the demands of the population of Ladakh is to be realized, this

sector must be given top priority. Vegetable productions are more advantageous and provide sufficient scope for value addition and commercialization. This will improve our people financial capacities and in turn can manage deficit quantities of other essential commodities.

Strateg I : Make vegetables cultivation more remunerative

1. Enter untapped sectors, and improve the quality of existing ones.
2. Organise a sustain marketing initiative.
3. Encourage the use of modern scientific method.
4. Multiple cropping.

Unexplored avenues, such as seed production should be explored. The quality seed is an important aspect of vegetable production as it greatly adds to grower's profit. Most of the annual crops produce seed in the same way as elsewhere in the country. But the seed production of biannual crops is different. There is a need of long storage of propagules (head, bulb, tap root etc.) during winter for seed production in next cropping season. Seed produced in Ladakh are not only healthy but also bold with more viability and germination. On the basis of research trails conducted at DIHAR (earlier FRL), potential of vegetable seed production. Leh valley is also considered ideal for production of disease free true potato seed (TPS). Almost no rains and long photoperiod during summer make this area very suitable for TPS production. The market for vegetables in Ladakh's remote areas (such as Changtheng) should also be tapped.

As far as second objective is concern, there is a need to build a strong marketing initiative in support of vegetable crops, block level and district level 'mandis' should be created. Cooperatives with strong networks within and outside the district should be promoted. Markets in large metros like Delhi, Chandigrah and Srinagar should be tapped, through such agencies as the HPMC (Horticulture Produce Marketing Corporation), cooperatives and mandi dealers. Transport facilities should be organised, firstly to get products from far flung areas in Ladakh to marketing centers, and then send these products outside the district (using refrigerated vans and air freight if required). The introduction of national and international companies into the region to buy our local land-based products (such as seed for instance) could also be explored.

Coming to the incorporation of modern scientific methods into the traditional agriculture, this should be achieved by encouraging the use of small efficient machines such as power-tillers into indigenous Ladakh agriculture practices. Plant and soil testing facilities and seed multiplication farms should be established, and the used of information technology and extension education should be explored fully. The availability of cold storage facilities in each block and at the district head quarter level will be an additional step in the right direction. Mega greenhouse structures can also be a success with few families coming together and taking the initiative. Innovative ideas and techniques from more advance regions with the same climatic and topographic conditions can be considered for replication. Growing more than one crop in a year per unit area or in a filed is known as multiple cropping. Three to four crops are generally taken on the same field within a year in major vegetable growing regions. Ladakh has got a short agriculture season so multiple cropping in this area is normally not practiced. Experiments at DIHAR Leh have shown that in some places where water is available from March to October it is possible to take two crops or even three crops in a single year. Some of the cropping patterns are as given below (Table):

200 percent cropping intensity	300 percent cropping intensity
1. Pea (Arkel/local) - Radish (Pusa Himani) April –Aug + Aug-Oct	1. Knol-khol (May-June) - Radish (July-August) – Palak (August- October
2. Knol-khol (White Vienna) - Turnip (PTWG) /Radish (Pusa Himani) April-July+ August – October	2. Vegetable mustard (April-June) –Radish (June-July) – Turnip (August-October)
3. Vegetable nursery-Onion/Cole crops/Root crops (April-may + June-October)	3. Coriander April-May) - Methi (June -July) – Vegetable mustard (August to October)

(Source: Singh and Singh, 2003)

Strategy II: Conserve the resources and the environment

1. Project water and soil.
2. Conserve soil moisture (mulching).

Under this head, the conservation of water resources, protecting available sources such as snow and natural glaciers must be taken up on priority, as the cultivation of vegetables in totally depended on irrigation water from these sources. The creation and maintenance of new artificial water bodies (such as artificial glaciers reservoirs fed by water harvested from seasonal nallahs etc.) should also needs to be paid attention in Ladakh, as soil erosion is a widespread phenomenon in this region. As part of a drive to conserve soil in the region, operation oriented soil conservation initiatives, an integrated watershed development programme for soil conservation, and pilot projects on soil conservation should be taken up. A major need to enhance production in the region is by conservation of soil moisture. And mulching is one of the practice through which we conserved soil moisture, temperature, and control weeds. In one of an experiment conducted at DIHAR using black polyethylene 150 guage thick as mulch in transplanted vegetable crops such as cauliflower, cabbage, tomato, brinjal and capsicum. Favourable response was observed in cabbage, cauliflower and tomato pertaining to ear liners and productivity. As given in Table 4.

Table 4. Effect of black polyethylene mulch on yield of vegetables in Leh

Crop	Marketable yield (q/ha)		Earliness days
	Mulched	Unmulched	
Cauliflower (Snowball K-1)	516	389	18
Cabbage (Golden Acre)	780	691	20
Tomato (Rupali)	617	428	16

Source : Singh *et al*., 2008]

Strategy III : Encourage research

Adaptive research has great scope in the region. Ladakh has different agro zones as mention above and every agro zone has different requirement. So the varietal development programme including hybrids as pertinent to each agriculture zone must be developed. The cold desert is rich in floral diversity and many plants are used to consumed as vegetables in the region by

local people from time immemorial. The natural cold desert flora used as vegetables that are given in the Table- , needs to be studied in detail for commercial exploitation on sustainable basis (Table 5).

Table 5. Natural cold desert flora used as leafy vegetables

Botanical name	Family	Local name
Allium wallichii	Amaryllidaceae	Skotche
Capparis spinosa	Capparidaceae	Kabra
Capsella bursapastoris	Brassicaceae	Shamso
Chenopodium botrys	Chenopodiaceae	Sagani
Christolea crassifolia	Brassicaceae	Kascheaff
Elsholtzia densa	Lamiaceae	Erzeot
Fagopyrum esculentum	Polygonaceae	Dyat
Lepidium latifolium	Brassicaceae	Sauson
Rumex patientia	Polygonaceae	Shoma
Sonchus oleraceus	Asteraceae	Khala
Urtica hyperborean	Urticuceae	Zingral

[Source : Singh *et al.,* 2008]

Green house technology and winter vegetable production in cold arid region of J&K

A greenhouse is a farmed or an inflated structure covered with a transparent or translucent materials which permit at least partial control of plant environment and which are large enough to permit a person to carryout cultural operation (Chandra and Panwar, 1987). The greenhouse effect is being used since long in many places to grow plants/crops under fully or partially controlled environmental conditions using electricity. However environmental controlled greenhouses are not popular in Ladakh simply because of acute shortage of electric power in the region.

Common available Solar Greenhouses in Ladakh

Though Ladakh is predominated by Ladakhi polyhouses, however studies carried out by Field Research Laboratory-Leh recommends trench type of greenhouse for the region. Common greenhouses available in Ladakh are:

1. Glasshouse

Perhaps this is the first and oldest among all types of greenhouse structures. Glass is the glazing material with glass panels fitted with the help of wooden or metal frame. Due to high temperature during summer it becomes unfit for cultivation during summer. High initial cost, difficulty in construction and frequent damage of glass panels by strong winds are certain discouraging factors. Such structures are not common in Ladakh.

2. Ladakhi polyhouses

The most common greenhouse in Ladakh is Ladakhi polyhouses. It is similar to normal but the only difference is its surrounding mud brick wall in place of polyethylene sheets which not only cut down the installation cost but also reduces the adverse effects of strong winds and also increases the temperature retention and ultimately net profit get increased. This is generally lean type, have three sides made of mud bricks. The two side walls descending towards the front. J and K State Deptt. Of Agriculture/Horticulture provide cash subsidy of Rs.3000 besides 32x16 ft. free polyethylene sheet. This has brought boost to greenhouse revolution in Ladakh.

3. Trench (underground greenhouse)

This is a very simple, cheap and useful greenhouse structure for Ladakh and, thus, has unlimited potential in the region. This may be of any convenient dimensions. This is a pit type structure where wooden poles are used to hold UV stabilized polyethylene film. This is again covered by and additional polyethylene sheet or woolen or cotton sheet during night to reduce the heat loss in extreme winter. Damage by wind is minimized. The structure does not require much skill in its construction and management. Its cost is lowest among all other greenhouses (table) and being an underground structure heat loss is minimum and temperature retention is high (Singh and Daulakhandi, 1998) and thus yields good crop. The structure is thus most suitable for the region.

4. Tunnel

It is a small semispherical structure frame made of metal, wood or plastic and covered with polyethylene or fiber reinforced plastic to create protected environment. These structures serve as mini greenhouse. This is a temporary structure which can be shifted to any place. It is generally used for winter vegetable production and early vegetable nursery raising. Major problems are faced in watering, weeding and harvesting.

Use of Green houses

Over the period of decade all the above types of greenhouses have been evaluated for suitability of various aspect of vegetable production. The study reveal that the greenhouses could be used for the following purposes in high altitude cold arid conditions.

1. Cultivation of vegetables during winter months at subzero temperature when it is not possible to grow in open field.
2. Vegetables like cucurbits, capsicum, brinjal, okra etc. are rare in Ladakh but these crops can be grown in greenhouse during summer.
3. Raising vegetable nursery earlier and advancing vegetable availability is also possible by use of greenhouse.
4. Greenhouse provides an excellent opportunity to produce quality vegetable for export.
5. Greenhouse (local) is ideally suited for Ladakhi farmers having small holdings.
6. It provide a soothing green look in monotonous snowing environment.

Status of greenhouse in Ladakh

Crop season is short and entire Ladakh region remains cut off from the rest of the country for 7 to 8 months. Therefore self sustenance is not only desired for this region but it is mandatory aspect of development. Acute power crisis in Ladakh has resulted development of solar greenhouses in the region. There is not a single greenhouse available in the region with controlled climate device. But the region receives abundance sunshine, 300 sunny days per year (2150 KWh per year) even in December the minimum radiation is 4.32 KWh per day ((Sodha *et al.*, 1988), which can be best utilised by solar greenhouses. The most common greenhouse is polyhouse constructed by using locally available materials like mudbricks, wood and polyethylene. UV stabilized cladding film is used for these Ladakhi polyhouses.

State Government (J&K) provides subsidy through various agencies like agriculture/horticulture department to farmers for construction of Ladakhi polyhouse. Several other agencies likes various NGO (LEHO and LEDeG) also promote the construction of the greenhouse in the region. This has resulted in a greenhouse revolution in Ladakh. Approx 15,000 greenhouses (Table) are available in Leh district which is perhaps the largest in the country. 'Nang' the remotes village of Ladakh, is having 55 greenhouse one each with all 55 families.

Features of ideal greenhouse for Ladakh

Peculiarity of Ladakh weather that is very high temperature fluctuations, strong winds and high light intensity coupled with UV radiation needs a different type of greenhouse for the region. Since the region is isolated from the main land and remain landlocked for most of the months of year, hence all required materials for greenhouse must be locally available and cheap in cost so that poor farmers can afford the expenditure. Cost of different greenhouse per M_2 per year has been worked by Singh *et al*. has been given in (Table 6).

Table 6. Cost of different greenhouse per M^2 per year (Rs.)

Structure	Total cost	Life span (yr.)	Area (m^2)	Cost (m^2/yr.)
Glasshouse	115200	10	40	288.00
Ladakhi polyhouse	5240	3	50	34.94
Polyhouse	52000	2	47	125.00
Trench	1960	6	24	13.59
Tunnel	6240	2	140	22.29
Unit polyhouse	5300	2	70	37.86

[Source : Singh *et al*., 2000]

The greenhouse must be capable enough to trap the solar energy and produce vegetable even at sub-zero temperatures (Tewai and Dhiman, 1986). It should also be strong enough to resists the strong cold waves and extremely low temperature. The structure should be simple and easily manageable so that even a lay man can built and manage it without any difficulty.

Selection of suitable vegetable crops for greenhouse
Suitable vegetable for winter

Selection of vegetable crops for winter cultivation is the most important factor. The crop should not only tolerate the subzero winter temperature but should also grow under cover where diffused sunlight is available. Fast growing and raton yielding crops should be preferred so that more number of cutting can be taken. After conducting various studies it has been found that leafy vegetables like beet leaf (palak), coriander, lettuce, fenugreek, parsley, celery, vegetable, mustard and mint are the most suitable crops for winter vegetable cultivation in Ladakh. Their comparative growth and yield under greenhouse condition has been given in Table-. Root crops like radish, beetroot, carrot, turnip can also be grown successfully.

Problems or constraints in protected vegetable cultivation in Ladakh

1) The basic cost of fabrication and the operational cost of the climate controlled greenhouse are very high, which don't suit to the growers in Ladakh.
2) No specific breeding work has been initiated for development of suitable varieties/hybrids for protected cultivation, even in important vegetables viz., tomato, sweet pepper and cucumber.
3) Cladding materials of required quality is not available, which is an important aspect of protected cultivation in such harsh environment.
4) Vegetable production technologies of potential vegetable crops under different types of protected structures have not been worked out.
5) There is a lack of packaging and on farm value addition, for supply of the high quality produce to upmarkets.

Prospects of protected cultivation of vegetable in Ladakh

Protected cultivation of vegetable is a boon to the cold desert of the country where this technology is suitable for commercial cultivation for several vegetables and production during frozon winters when nothing can be produced outdoor. The trench and polyhouse (local design) have been willingly adopted by farmers in Ladakh, because of their low cost, simplicity and ease of operation. It is easy to manually manipulate environment in trenches necessitated by sudden and frequent changes in the weather-this aspects makes trench most suitable for Ladakh condition. Cost of cultivation in greenhouses was worked out. Local polyhouse and trench were found cheaper for production of vegetables as their cost of construction is low and heat retention is better. The below given Table shows the average return of different protected structures during winter months. In trench it was Rs. 2036, from local polyhouse Rs. 1280 and from glasshouse Rs. 214 from an area of 50 m^2.

Table 7. Average return from greenhouse (50 m^2 area) during winter

S. No.	Greenhouse	Average return (Rs.)
1.	Trench	2036
2.	Local polyhouse	1280
3.	Polyhouse	400
4.	Glasshouse	214

[Source : Defence Institute for High Altitude Research (DRDO) Leh]

The potential of protected vegetable cultivation to meet the demand should not be overlooked. Protected cultivation provides many fold advantages over open field vegetable cultivation. Its highly productive, conserves water, fertilizer and land. It is also eco-friendly. Subzero temperature in greenhouse can be avoided by providing adequate thermal storage mass as suggested by Tewari and Dhiman (1986). This can be done by making thicker walls and insulating them. Thermal screen during night within greenhouse one foot above the crop was found effective to maintain temperature above freezing. There are other attractive options, however it may not work in Ladakh as there is shortage of electric power in Ladakh. Despite the limitation scope exists for expansion of greenhouse area in cold desert of India, as it has rapidly taken place in China. In cold desert of India, solar greenhouses are gradually being updated to make them popular. It clearly emerges that greenhouse technology has multipurpose application for sustainable development of cold arid zone. Harshing winter which otherwise threatens the survival of human beings in these remote areas, popularization and further improvement in greenhouse could provide a sign of relief in solitude of white snow cover. Thrust area for future research

are enumerated below :

1. Conservation of more thermal radiation in winter.
2. Durable infrastructure modelling.
3. Evaluation and improvement of a agronomic technique for raising vegetable in greenhouse.
4. Identification of new crops/varieties suitable for cultivation inside the greenhouse.

Conclusion

Vegetable production in Ladakh has great potential but research on many aspects are still lacking. There is an urgent need to lift this land based economy and make the region more self reliant like it used to be.

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