Defence Science Journal, Vol. 61, No. 2, March 2010, pp. 219-225

REVIEW PAPER

Protected Cultivation for Food and Nutritional Security at Ladakh

Gyan P. Mishra*, Narendra Singh, Hitesh Kumar, and Shashi Bala Singh

Defence Institute of High Altitude Research, C/o 56 APO, Leh, Ladakh, J&K-901 205
**E-mail: gyan.gene@gmail.com*

ABSTRACT

Ladakh, being cold, arid, high altitude region of India has a very harsh climate and a short agriculture season. Due to extreme long winter, the agriculture season is short, which extends from May-September in general, and in case of particular location, it depends upon altitude. Although the greenhouse technology is more than 200 years old but with the advent of plastics during the World War-II, a new phase in the greenhouse technology has emerged. The Defence Institute of High Altitude Research (DIHAR), one of the DRDO laboratories, is providing adequate support and technological help to set various types of green houses, both for the Army Units deployed in the far-flung areas and for the local farmers in the Ladakh. Till date, there were 65 greenhouses being established by DIHAR in most of the Army Units deployed in the 'L' sector with the average vegetable production of around 2000 kg/greenhouse/year. At present, the much needed vegetables are being grown throughout the year in these hostile climates under protective cultivation, which not only gives them the fresh food but also the nutritional security of the troops deployed.

Keywords: Protective cultivation, high altitude cultivation, greenhouse technology, nutritional security, high altitude agriculture, high altitude agro-animal technologies

1. INTRODUCTION

DRDO is engaged in research for men behind the weapons since it is also needed to look into their needs. This mission is led by DRDO Life Science Laboratories and Defence Institute of High Altitude Research (DIHAR) is one of these, which has specialisation in high altitude agro-animal technologies. Of all the basic human needs, food is the most essential, and providing food to the troops has posed the greatest challenge because of their deployment on remote frontiers location and timing of operations. This has been aptly summarised by Frederick as 'An army fights on its belly' or by Nepoleon as 'An army marches on its stomach'. All over the world, Armed Forces are supplied foods according to ration scales designed by nutritionist to suit food habits of the troops, place of deployment, climatic conditions, nature of duty, and economic availability of food.

Vegetables contributed major part in the human diet for balanced nutrition. Vegetables are rich sources of minerals, protein, vitamins, and dietary fibres which can not be supplied by other food sources. The basic recommended quantity of vegetables for Indian soldier per head per day is 140 g potato, 60 g onion, and 170 g fresh vegetables. To maintain the regular supply of fresh vegetables to our troops at our frontiers like Siachen, Kargil, Battalic, Drass in Ladakh sector of Jammu & Kashmir and along China/Tibet border is not an easy task. Since the region remains landlocked for over seven months in a year due to heavy snowfall which closes the road passes from November to May every year. During road-close period, the vegetables reach Ladakh through air route which costs the freight charges around 131 Rs/kg. While during road-open period (June to October), regular supply of fresh vegetables cannot be maintain, since transportation cost and losses are very high due to long distances involved in the supply chain and perishable nature of vegetables.

In spite of multitude of constraints, this laboratory has developed vegetable production technologies for boosting the local availability of fresh vegetables for troops through local farmers. This has drastically reduced the government expenditure on transportation, both via road and air. This has also generated employment for the rural tribal farmer of the region since they are growing a number of high yielding vegetable varieties/hybrids in their farms. At present, DIHAR has standardised the cultivation practices of 65 different types of vegetables for the high altitudes and by adopting the DIHAR technologies, local farmers are supplying fresh vegetables (29 types) covering tropical, sub-tropical, and temperate oregion to the Army. Farmers cooperative marketing societies are ensuring supply of about 3,600 MT vegetables to Army and meeting about 56 per cent of total requirement of fresh vegetable in Ladakh sector in 2007-2008. This has developed unique relation between Army and the civilian population. This success story is a unique example of partnership among scientists, Army, and farmers.

Indian cold arid region comes under the trans-Himalayan zone and covers about 80,000 km^2 land mass. More than 90 per cent cold desert of India is situated in Jammu & Kashmir state as Ladakh region. Due to extreme long winter,

Received 02 November 2009

the agricultural season is short, and which extends from May–September in general, and in case of particular location, it depends upon altitude (Table1)[1].

Table 1. Cropping season and duration at different altitude[1]

Altitude (m amsl)	Cropping season	Duration (in month)
2400 – 2700	April – October	7.0
2700 – 3000	May – Mid-October	5.5
3000 – 3300	Mid-May – September	4.5
3300 – 3600	June – Mid-September	3.5
3600 – 4000	Mid-June – August	2.5

Wide variation in daily and seasonal climate makes it difficult to standardise package of practices for cultivation of vegetable crops in the region. Among the climatic factors, temperature is most important which has great impact on cropping pattern and production techniques. Since temperature decreases with increasing altitude, therefore, cropping season and duration depend upon the altitude (Table 1). Although, Army is deployed up to 6,600 m altitude in the region but human settlement and agriculture is confined between 2,400 m to 4,200 m altitudes. For enhanced production of vegetables to ensure the nutritional security in high altitude cold desert, a comprehensive research programme was carried out at DIHAR on various aspects of vegetable production during the last four decades[1].

2. PROTECTIVE CULTIVATION

Protective cultivation practices can be defined as cropping techniques wherein the micro climate surrounding the plant body is controlled partially/fully, as per the requirement of the plant species grown, during their period of growth. With the advancement in agriculture, various types of protective cultivation practices suitable for a specific type of agro-climatic zone have emerged. Among these protective cultivation practices, greenhouse/polyhouse are extremely useful for round-the-year vegetable cultivation in the Ladakh region.

3. PRINCIPLES OF GREENHOUSE CULTIVATION

The term greenhouse means different things to different people. A greenhouse used to be a structure formed of glass, with a heating (or cooling) system that was used year-round, but especially in winter. A greenhouse is generally covered with a transparent material such as polythene or glass, now a days normally polycarbonate sheets are used because of their longevity (up to 12 year), durability, and transparency. The greenhouse covered with simple plastic sheet is termed as polyhouse. Depending upon the cladding material and its transparency, major fraction of sunlight is absorbed by vegetable crops and other objects. These objects in greenhouse in turn emit long wave thermal radiations for which cladding material has lower transparency. With the result, solar energy is trapped and it raises the temperature inside the greenhouse. This is popularly known as greenhouse effect. This rise in temperature in greenhouse is responsible for growing vegetable in cold climates. The greenhouse generally reflects back 43 per cent of the net solar radiation incident upon it allowing the transmittance of the 'photosynthetically active solar radiation' in the range of 400 – 700 nm wavelength. However in the summer season, due to the above-stated phenomenon, ventilation and cooling is required to maintain the temperature inside the structure well below[2] 35 ^{o}C.

4. PRESENT STATUS *VIS-A-VIS* GLOBAL AND NATIONAL SCENARIOS

The greenhouse technology is more than 200 year old and Europeans were considered the pioneers in this field. Later, with the advent of plastics during the World War II a new phase in the greenhouse technology emerged. At present nearly 90 per cent of the new greenhouses are being constructed by utilising ultra violet (UV) stabilised polythene sheets as the glazing material. In India, the technology is still in its nascent stage. The area under greenhouse cultivation, as reported by the end of 20th century was about 110 hectare in India. This figure is quite significant when compared with the total area under greenhouse in the world which was 275,000 hectare as reported for the year 1999–2000. Thus, it can be safely stated that there exists a vast scope for expansion of greenhouse technology in India, especially for Ladakh.

Application for the greenhouse technology for commercial purpose is however in its infancy in India. The greenhouses which existed in 1960s were used for commercial purposes but the impetus and the much required thrust came only in the mid 1980's with the emergence of the industries manufacturing UV-stabilised low-density polyethylene (LDPE) and the development of the indigenous technology for low-cost greenhouses. Today, there are more than 3000 small and medium sized greenhouses at Leh. At present, the much needed vegetables are being grown throughout the year in these hostile climates. Production of brinjal, capsicum, tomato, and other cucurbits is taken in the summer months on a large scale, whereas the green leafy vegetables are being grown in the long frozen winter months when the average temperature reaches up to -40 ^{o}C. Underground greenhouses and soil trenches are also being used on a large scale in these remote areas[2].

5. LADAKH AND THE COLD DESERT VEGETABLES

Ladakh, the land between the earth and the sky is considered virtually unfit for vegetation. But long ago, some plant species were able to establish themselves in this difficult terrain after natural introduction. Majority of such plants are perennial herbs and some of them were suitable to use as vegetables (Table 2)[3]. Before introduction of some cultivated vegetable crops such as turnip, radish, carrot, onion, potato and certain leafy vegetables in late 1950s by the government officials (foreigner and Indian) and missionaries, the people of this region were dependent on these wild plants species as vegetables and this practice can still be seen in far-flung villages.

Table 2. Production potential of natural leafy vegetables of cold desert Ladakh[1]

Vegetables	Common name	Leaf yield/cutting (kg/m^2)
Chenopodium botrys	Sagani	0.8
Fagopyrum esculentum	Buckwheat	0.7
Lactuca dalichophylla	Khala	1.4
Lepidium latifolium	Dittander	0.7
Oxyria digya	Mountain Sorrel	0.7
Rumex patientia ssp	Shoma	1.0
Urtica hyperborea	Zacchaut	0.9

After establishment of DIHAR (1962), systematic experimentation was carried out and many new vegetables were introduced and production techniques evolved and demonstrated. After that, the farmers of this region started cultivation of various types of vegetables such as cabbage, cauliflower, knol-khol etc. Up to the 1970s, vegetables were mostly grown through direct seed sowing in the month of June every year and fresh vegetables were available only for 2 months (August and September of that year). The availability period of vegetables cultivated in open fields during summer season has been enhanced from 2 to 5 months (June–October) by protected nursery-raising techniques and introduction of more number of suitable vegetables varieties/hybrids. After introduction of cucurbitaceous, solanaceous, and exotic crops in the last decade, total number of introduced vegetables has been increased and agro-techniques have been evolved for more than 65 types of vegetables[4]. Techniques have also been standardised to produce more than 20 types of vegetables even during severe winter months (October – April) through greenhouse technology[5].

6. VEGETABLES FOR NUTRITIONAL SECURITY AND HEALTH OF MILITARY PERSONNEL

Vegetables are potential source of vitamins, minerals, carbohydrates, proteins, and fibres. These are the essential ingredients of a balanced human diet to meet daily requirements. High nutrition value of leafy vegetables produced in trenches under cold desert condition of Leh was also reported by Yadav[6], *et al*. Vegetables are usually higher in productivity than other crops. Solanaceous vegetable like tomato can be yielded over 200 ton/hectare in protected conditions and more than 60 ton/hectare in open field conditions in cold desert[7]. Likewise, cabbage has much higher yield potential (120 ton/hectare) than cereal crops[4] while garlic can be used to cure cough and cold. Even serious diseases can also be prevented by particular vitamins/minerals-rich designer product from the vegetables[8].

7. VEGETABLES REQUIREMENT IN COLD DESERT

To fulfill the requirements, it is difficult to import the vegetables from other parts of the country to Ladakh mainly due to their highly perishable nature and involvement of long distance transportation. The region remains land-locked every year from November–May due to heavy deposition of snow on the road-passes. Air-lifting of the fresh vegetables results in heavy expenditure, which will not be affordable by the people. Army also requires huge quantity of fresh vegetables to feed their troops deployed in this region and spends a substantial amount to import the vegetables from other parts of the country. Including army and floating population, vegetables are required for a population of about 3.0 lakh in the region. If it is calculated based on the ration scale provided to the Army, then total of 37,200 metric ton/year vegetables are required (Table 3). Out of this quantity approximately 17,705 metric ton/year vegetables are produced locally and remaining quantity is either imported from other places of the country or the people replace it by other food ingredient in absence of availability of vegetables[1].

Table 3. Total requirement and local production of vegetables in Ladakh[1]

Items name	Requirement (metric ton/year)	Production (metric ton/year)
Vegetables	17000	8160(>30 types)
Potato	13000	8450
Onion	5400	1080
Garlic	1800	15
Total	**37200**	**17705**

8. GREENHOUSE TECHNOLOGY AND COLD DESERT

Greenhouse technology is the technique of growing crops by providing favorable environment/growing conditions to the plants. It is used to protect the crops from adverse climatic conditions and to provide optimum conditions of soil, light, temperature, humidity carbon dioxide, etc for the best growth of the plants to achieve maximum yield coupled with quality. A greenhouse which is a covered by structure (transparent cladding material) also protects the plants from high wind velocity, excess evaporation, unusual precipitation, and temperature extremes. The CO_2 released by the plants during nighttime is also trapped inside the greenhouse which is subsequently taken up by the plants itself during daytime in the presence of light, and thus enhances photosynthesis. All the above factors contribute in 3–5 times higher yield of crops under greenhouse condition, as compared to open-field conditions.

Greenhouse cultivation practices for Ladakh have been standardised by DIHAR for raising early nursery of vegetable crops, cultivation of leafy vegetables during extreme winters ,and cultivation of tropical, subtropical, and temperate vegetables during summer. Several army units in 'L' sector are located in far-flung areas along LOC under extreme hostile environment where availability of fresh vegetables is very scarce. At present, around 65 greenhouses have

been installed by DIHAR at various Army units which are managed by the troops under technical supervision of the Laboratory and produce is consumed by the units throughout the year. This has not only improved the availability of fresh vegetables in forward army locations but also helps in increasing their moral in hostile climatic conditions.

Without using greenhouse effect, it is difficult to think about vegetable production during winters when temperature goes beyond -20 °C. Therefore, research work was targeted towards greenhouse technology for Ladakh after establishment of DIHAR and various greenhouses have been designed, evaluated, and demonstrated for different aspects of vegetable production. Under the study, nine types of greenhouses were evaluated and identified suitable for various aspects of vegetable production such as round-the-year vegetable production, protected nursery raising, seed production and particular vegetable/variety production at a particular time[9]. Design of polycarbonate and fibre-reinforce polyester (FRP) sheet-clad greenhouses are found most suitable for production of indeterminate hybrid of tomato, capsicum, chilli, brinjal, gynacious hybrid of cucumber and zucchini during summer months from 2,400–3,600 m altitude and leafy vegetables, i.e., Swiss chard, beet leaf, kale, lettuce, etc. during winter. Above 3,600 m altitude, selection of the crops suitable to grow in the greenhouse is changed as cabbage, cauliflower, radish, turnip and short duration varieties like 'Pusa Sadabahar' and 'Sindhu-1' of tomato[7]. The polyench greenhouse made of locally available material except cladding material is found suitable to raise early nursery and round-the-year production of leafy vegetables[10]. However, the trench greenhouse is most suitable to produce off-season potato[11], vegetable nursery and certain leafy vegetables during March–May[12]. The early protected, nursery especially of cucurbitaceous crops, can be produced in seasonal greenhouse as they provide better scope for hardening of the seedlings before transplantation[1].

Economics is also an important factor to utilise the greenhouse for different aspects of vegetable production. DIHAR has evaluated and recommended economically viable crop rotations and production techniques of the crops for different greenhouses. Tomato (indeterminate hybrid) during summer months (April–October) and Swiss chard during winter months (November–March) give highest return (1:1.8 benefit ratio) in FRP greenhouse, however, leafy vegetables like beet leaf, Swiss chard and kale during winter months (September–May) and radish during summer months (June–August) found most viable crop rotation for polyench (1:3.2 benefit ratio)[7]. The data presented in Figure 1 revealed that due to low construction cost and high production, single and double wall polyench have low production cost followed by trench[1].

Since vegetables are highly perishable but essential part of human diet, and army spends a substantial amount on transportation (by air and road) of fresh vegetables up to the forward locations of their deployment. The harsh environmental condition of Ladakh does not allow much scope to diversify and increase yield potential of vegetable crops. In this regard, DIHAR has standardised various components of vegetable production under protected conditions and developed solar-based appropriate and sustainable greenhouse technology for cold desert areas. The Laboratory has designed several greenhouses for year round cultivation of crops.

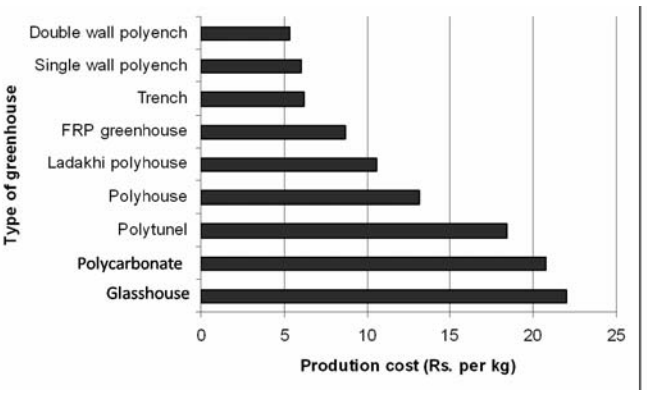

Figure 1. Cost of vegetable production in various greenhouses[1]

9. TYPES OF GREENHOUSES

9.1 Low-cost Greenhouse

The low-cost polyhouse is a zero-energy chamber made up of polythene sheet of 200 μ supported on wood sticks with ropes and nails. It is used for protecting the crop from high wind and precipitation, mostly in the form of snowfall. Its size depends upon the purpose and availability of space. The structure depends on the sun for energy. The temperature within polyhouse increases by 6–10 ^{0}C more than outside. In UV-stabilised plastic film-covered, wood-framed polyhouse, the day temperature is higher and night temperature is lower than the outside. The solar radiation entering the polyhouse is 30–40 per cent lower than that reaching the soil surface outside the polyhouse.

9.1.1 Trench

During the technology-generation stage, special attention was given to resource poor farmers of Ladakh, for which the Laboratory has designed trench greenhouses which are made of locally available material except UV-stabilised transparent polythene. It is a low-cost greenhouse termed as an underground greenhouse preferably 30 x 10 x 3 cubic feet of size. Trench is covered with transparent UV-stabilised 200 μ thick polythene during daytime to harvest maximum solar energy and extra cover of black polythene at nighttime to check the heat loss (Fig. 2). It maintains average 7–8^{0}C difference in temperature during winter. The production cost under trench is 5.25 Rs/kg and cost benefit ratio is 1:3.5. It reduces evapo-transpiration losses and maintains 7 ^{o}C differences in temperature during winter. The production cost under polyench is 5.25 Rs/kg and cost benefit ratio is 1:3.2. Cost of production of spinach in different greenhouses/m^2/year is presented in Table 4.

9.2 Medium-cost Greenhouse

With a slightly higher cost, a quonset-shaped polyhouse (greenhouse) can be framed with GI pipe (Class B) of 15 mm

Figure 2. Spinach cultivation in the trench during severe winter.

Figure 3. Double walled polyench (outside view).

bore. This polyhouse will have a single-layer covering of UV-stabilised polythene of 800 gauge. The exhaust fans are used for ventilation. These are thermostatically-controlled. Cooling pad is used for humidifying the air entering the polyhouse. The polyhouse frame and glazing material have a life span of about 20 year and 2 year, respectively.

9.1.2 Polyench

It is semi-underground double-walled greenhouse working on the principle of zero-energy chamber made from locally available unbaked bricks and wooden ballies. It enhances 11–12 °C temperature and 40 per cent humidity as compared to ambient daytime during extreme winters and provide favourable environment for vegetable cultivation, especially leafy vegetables and root crops. The cost benefit ratio is 1:4 (Figs 3 & 4).

Figure 4. Capsicum cultivation in double-walled polyench (inside view)

9.3 High-cost Greenhouse

It is constructed on the structure (frame) made of iron/ aluminium structure, designed domed-shaped or cone-shaped (as per choice). Temperature, humidity, and the light are automatically controlled as per requirement of the users. Floor and a part of walls are made of concrete. It is highly durable, about 5–6 time costlier, required qualified operator, proper maintenance, care, and precautions while operating.

The low- and medium-cost greenhouses have wide scope in production of domestic as well as export-oriented vegetables. Ladakh region recorded temperature upto -40 °C during sever-winters due to which it is impossible to grow the vegetables during this period under open conditions. So, growing of vegetable crops in a low-cost greenhouse during this period is very profitable. Control of disease and pest in greenhouse is also easy.

9.3.1 FRP (Fibre-reinforce Polyester) Greenhouse

This laboratory has evaluated, standardised and disseminated FRP greenhouse technology to both the army and the local farmers. FRP greenhouses of size 100 x 30 sq feet were installed at various locations of 'L' sector along with technical knowhow and inputs to ensure round the year availability of fresh vegetable. Also ensured 200

Table 4. Cost of production of spinach in different greenhouses/m²/year (in Indian Rs)

Structure	Total cost (Rs)	Life span (Yr)	Area covered (m^2)	Cost (m^2/yr)	Prod. cost (Rs/m^2/yr)	Crop yield (kg/m^2)	Value of produce @15/kg	Profit (Rs/m^2/Yr)
Ladakhi polyhouse	5240.00	3	50	34.94	35	5.4	81.0	46.0
Polyhouse	50000.00	2	70	125.00	125.00	2.7	40.5	-84.5
Trench	1960.00	6	24	13.59	14	6.3	94.5	80.5
Tunnel	6240.00	2	140.00	22.29	22	2.2	33.0	11.0

per cent cropping intensity with nursery raising under triple-layered greenhouse (Figure 5).

Figure 5. Tomato crop in the FRP greenhouse.

9.4 Other Plant Protection Structure

9.4.1 Plastic Low Tunnels

Plastic low tunnels are miniature form of greenhouses to protect the plants from precipitation, winds, low temperature, frost, and other vagaries of weather. The low tunnels are very simple structures requiring very limited skills to maintain, are easy to construct and offer multiple advantages. For construction of low tunnels, film of 200 μ is sufficient (Fig. 6).

10. BENEFITS OF A GREENHOUSE

10.1 Vegetable Forcing for Domestic Consumption and Export

During winters in Ladakh region, the temperature and solar radiations are sub-optimal for growing any vegetables. Hence during extreme conditions of winter season (October–February), leafy vegetables like Swiss chard, Spinach, coriander, fenugreek, etc will be cultivated under greenhouses. The high-priced vegetables such as asparagus, broccoli, leek, tomato, cucumber and capsicum are most important crops for production during winter season or off-season.

Figure 6. Poly-tunnel greenhouse for garlic cultivation during extreme winter.

10.2 Protected Vegetable Nursery Raising

Nursery-raising is a highly technical aspect and has great impact on planting time, availability period, yield, and quality of the produce. Successful production of the certain vegetables like solanaceous fruit crops and cucurbitaceous crops in field conditions depend on early preparation of seedlings. Therefore, to get the early produce of the vegetables, practices have been standardised for healthy and vigorous seedlings raising of more than 40 types of vegetable crops in different types of protected conditions, like specific polycarbonate greenhouse, trench, polyench and seasonal greenhouses[4]. During the period DIHAR has developed the capacity to raise more than 9.0 lakh seedlings of different vegetables annually in protected conditions. The nursery raised in the greenhouse is ready for translation in first week of April (45 days early) for protected vegetable cultivation and this helps to get the produce about 60 days early than in open condition, with increased yield up to 60 per cent depending upon the crop[7].

The cucurbits are warm season crops and are sown in last week of May to June when night temperature is around 18 – 20 ^{0}C. But in greenhouses, their seedlings can be raised during March and April in polythene bags. By planting these seedlings during end of May and first week of June in the field, their yield could be taken in one and one-and-a-half month in advance than the normal method of direct sowing. Similarly, the seedlings of tomato, chilli, capsicum, brinjal, cucumber, cabbage, cauliflower and broccoli can be grown under plastic cover protecting them against frost and severe cold.

The environmental conditions, particularly increase in temperature inside greenhouses, hastens the germination and early growth of warm-season vegetable seedlings for raising early crops in spring summer. Management of vegetable nursery in protected structure is easier and early nursery can be raised. Needless to emphasise, this practice eliminates danger of destruction of nurseries by cold temperature and also provides protection against biotic stresses.

11. FUTURE POTENTIALITIES

The greenhouse technology is still in its preliminary stage in the country and concerted efforts are required from all concerned agencies to bring it at par with the global standards. Economically viable and technologically feasible greenhouse technology suitable for the Indian agro-climatic and geographical conditions is needed at the earliest. Work should be channelised in finding suitable and locally available construction material for low- and medium-cost greenhouses. Utilisation of the solar energy stored in the solar photovoltaic cell or else the heat rejected from the steam turbines of the thermal power plants for

greenhouse heating and humidity control needs to be improved.

As the area under greenhouse houses in India is likely to increase in the near future, the concerned industries should make earnest efforts to provide the much needed support in the hardware and software fields. Government initiatives/efforts in popularizing the greenhouse technology among the farming community of the country are to be strengthened. There is a need for the Government to encourage the farmers by providing timely subsidy for taking up this new technology in a big way[2].

12. CONCLUSIONS

There is very good and sustainable demand for fresh vegetables around the cities and towns along with the army deployed in the 'L' sector. The study on greenhouse technology was carried out by DIHAR, keeping in mind that the troops deployed in the 'L' sector need fresh vegetables in their diets for better nutrition's and health. At present, the much needed vegetables are being grown throughout the year in these hostile climates under protected cultivation. Production of brinjal, capsicum, tomato and other cucurbits is taken in the summer months on a large scale, whereas the green leafy vegetables are being grown in the long frozen winter months when the average temperature reaches up to -40 ^{o}C. Underground greenhouses and soil trenches are also being used on a large scale in these remote areas. Due to the various types of greenhouses, DIHAR is able to grow 78 different types of vegetables, the largest in number in a single season during April–September 2007. The vegetables ranged from tropical to subtropical and temperate types and included cole crops, root crops, bulb crops, legumes, solanaceous crops, leafy ones, cucurbits and spices. Under greenhouse conditions the yield is 3-5 times more than the open field conditions. To cater the vegetable needs of the local population and army in the inaccessible areas like Ladakh greenhouse cultivation could be an answer.

REFERENCES

1. Singh, N.; Singh, R.; Kumar, H.; Bhoyar, M. & Singh, S.B. Sustainable vegetable research for nutritional security and socio-economic upliftment of tribals in Indian cold deserts. *In* Advances in Agriculture, Environment and Health, edited by S.B. Singh, *et al*. SSPH Publication, New Delhi, 2008.
2. Diver, S. Organic greenhouse vegetable production horticulture systems guide: NCAT Agriculture Specialists, ATTRA Publication No. IP078, 2000.
3. Chaurasia, O.P.; Singh, N. & Singh, B. Potential wild leafy vegetable from Ladakh. *Indian Horticulture,* July–September, 2000, 4-5.
4. Singh, N. & Singh, B. Ladakh mein sabji utpadan (Vegetable production in Ladakh), Field Research Laboratory, Leh-Ladakh, 2003.
5. Singh, N. & Ahmed, Z. Solar greenhouse technology for vegetable production in high altitude cold arid region. Field Research Laboratory, Leh-Ladakh, 2005.
6. Yadav, J.; Singh, N. & Kumar, N. Nutritional values of off-season leafy vegetables grown in trench under cold arid conditions of Leh. *Agricultural Sci. Digest,* 1999, **19**(2), 103-04.
7. Pilot scale research cum demonstration unit for round the unit vegetable cultivation in 'L' Sector. Project Closure Report, SL-P1- 2001/FRL-99. 2004.
8. Biplab, K.N. & Bhattacharjee, L. Emerging issuses in nutritional security. *In* National Conference on Food Security and Vegetables: A Global Prespective. Dr. Prem Nath Agricultural Science Foundation, 2004, Banglore.
9. Singh, N.; Dwivedi, S.K. & Paljor, E. Protected vegetable cultivation in Ladakh (*Hindi*). Field Research Laboratory, 1999. Leh- Ladakh, India.
10. Singh, N. & Ahmed, Z. Double walled polyench greenhouse. *Indian Horticulture,* May-June, 2007, 8-9.
11. Singh, N.; Rout, B.; Kumar, N. & Mohanty, J.N. Off season potato production in trench in cold arid conditions of Ladakh. *J. of Indian Potato Asso.*, 2003, **30**(1-2), 95-92.
12. Singh, B. & Dhoulakhandi, A.B. Application of solar greenhouse for vegetable production in cold desert. *In* Renewable energy: Energy efficiency policy and the environment. Elsevier Science Ltd, UK. 1998. pp. 2311-314.

Contributors

Dr Gyan P. Mishra obtained his PhD (Genetics) from Indian Agricultural Research Institute, New Delhi. Presently he is working as Scientist 'C' in Vegetable Science Division, Defence Institute of High Altitude Research (DIHAR). His area of specialisation is molecular breeding.

Dr Narendra Singh has obtained PhD in Horticulture. Presently, he is working as Scientist 'D' in the Vegetable Science Division, DIHAR. His area of specialisation is high altitude vegetable cultivation technology.

Mr Hitesh Kumar is working as STA 'B' in the Vegetable Science Division, DIHAR. His area of specialisation is high altitude vegetable cultivation technology. He is actively engaged in the R&D activities for high altitude vegetable production technology of the institute.

Dr Shashi Bala Singh, see pp. 230.