

Protected vegetable cultivation for climate resilience and nutritional security in Eastern Ladakh, India

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Eastern Ladakh, India, experiences a harsh climate with temperatures dropping below zero, thus restricting agricultural activities for a short period. Therefore, the inhabitants depend completely on dairy products, packed and processed foods. Traditional farming practiced in the study region is purely indigenous and, by default, organic in nature. Therefore, the region has the potential to produce organic products under protected structures, which will be a source of income generation. The present study was conducted through frontline demonstrations at three locations, viz. Nyoma, Mudh and Tsaga in Ladakh for two consecutive years from 2019 under protected structures, viz. local greenhouse and low tunnel. A comparison of productivity levels between demonstrated variety and local checks was also made. A significant outcome was that the farmers have learned to produce quality vegetables not just to increase their income but also for nutritional security. There is a positive attitude among the locals on the importance of protected cultivation as a self-sustainable technology, nutritionally secure, and uplifting socio-economic conditions with climate-resilient features that will be a boon for this region despite extreme climatic conditions.

Keywords: Climate resilience, extreme climatic conditions, nutritional security, organic products, protected vegetable cultivation.

CHANGTHANG in the eastern part of Ladakh, India, is known for its wide rangeland, having harsh climatic conditions with minimum temperatures ranging from -22°C to -28°C up to elevation 4500 m amsl (Figures 1 and 2), thus restricting agricultural activities for a short period (3–4 months) in the summer season. Only a few vegetable crops like turnip, spinach, beet (locally known as Mongol), and potato are grown by the farmers in their kitchen gardens. Food and nutritional security is a major concern, which is receiving attention in developing countries like India. However, Ladakh's cold arid region, in particular, has been neglected to date. The tribal population living in Changthang is known as Changpas¹. They are mainly nomadic and semi-nomadic with a sedentary lifestyle and their economy is driven by the rearing of livestock², as agriculture is unsustainable in the cold high deserts. The tribals have adapted to a pastoral mode of life, rearing sheep, goat and yak for sur-

vival³. Although experiencing harsh climatic conditions and scarcity of resources, the pastoralists have been able to manage the environment until recently⁴. The scenario is now changing rapidly in response to socio-economic changes. Changthang suffers from hostile climatic conditions characterized by high wind velocity, dryness, intense solar radiation and precipitation in the form of snow and freezing stress⁵.

During winter, the region remains barren and isolated due to adverse climatic conditions. The major determinants are remoteness due to the topography of the region, hostile climate, market-access restrictions and limited agrarian resource potential⁶. Food consumption is primarily based on locally stored produce like potatoes, carrots, pulses, dried meat, dried leafy vegetables and tinned food in winter^{7,8}. Local peas and oats are grown as fodder species. In winter, the temperature drops to -3°C to -5.94°C even during daytime with high wind speed⁹. With the rise in altitude, there is a huge gap in vegetable production – the lowest recorded in Changthang (251 MT) compared to Leh (452 MT)¹⁰. The chilling temperature extends up to May, leading to frozen streams (khuls) at night¹¹, due to which the transplanted vegetables cannot withstand freezing stress in the early growth stage. Therefore, protected vegetable

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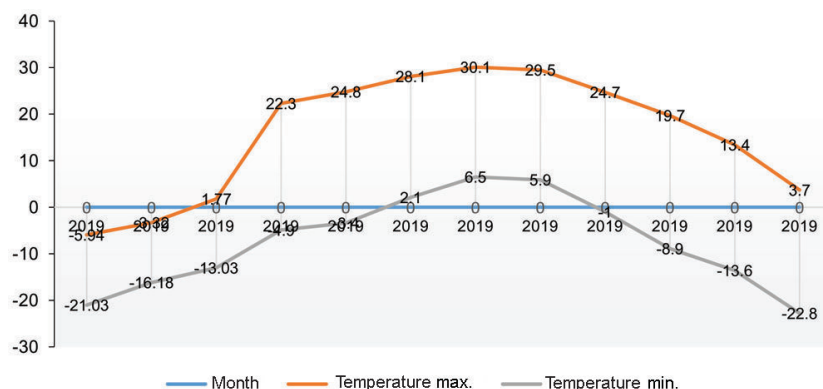


Figure 1. Agroclimatic data from Nyoma (4200 m amsl) Ladakh, India, under open conditions (2019). (Source: KVK Nyoma, 2019.)

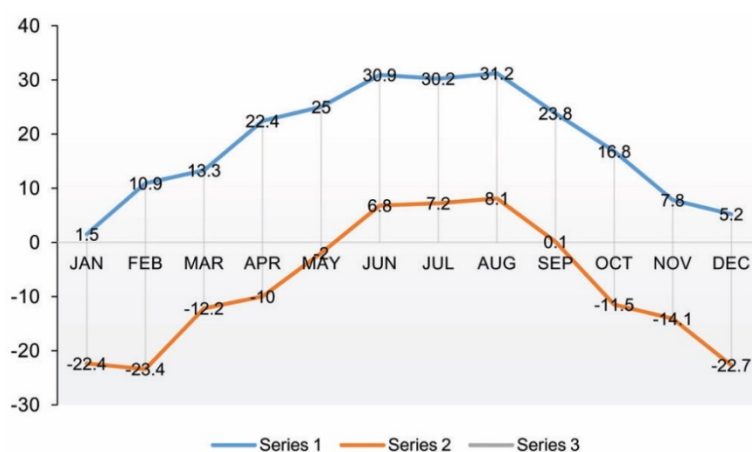


Figure 2. Agroclimatic data from Nyoma (4200 m amsl) under open conditions (2020). (Source: Krishi Vigyan Kendra, Nyoma, 2020.)

Table 1. Crop duration in open field versus different protected structures in the Changthang region, Ladakh, India

Field condition	Crop duration	Crop duration in open and different protected structures	Temperature (°C)
Open field	June to August/September	Field pea, garden pea, oats, barley, potato, turnip	15 to 30
Low tunnel	April to September	Vegetable seedlings, cole crops, bulb crops and leafy	18 to 42
Trench	March to October	Vegetable seedlings, cole crops, bulb, solanaceous, cucurbits	20 to 44
Greenhouse (mud-type)	All season	Vegetable seedlings, solanaceous, cucurbits, winter: leafy	-10 to 50

cultivation is a solution for climate resilience and nutritional security in Changthang (Table 1).

Research gaps

The extreme climatic conditions, poor connectivity and lack of research and development (R&D) particularly in this area remain neglected due to which directly affecting the vegetable production. Locals revealed that underexploited wild vegetables like zatsot (*Urtica hyperborea*), skotchche (*Allium przewalskianum*), Nyungma (*Brassica* spp.), Kosnyot (*Carium carvi*) are consumed. Vegetables like turnips, silver beet (Mongol), potatoes, kale and local pea are grown on a limited scale in the kitchen gardens, especially during the summer season. Vegetables are susceptible to freezing

and cold stress¹², which prevails throughout the year in this region. Fresh vegetables are generally purchased from the markets at high prices for the daily needs of the locals. Also, there is less consumption of vegetables and more consumption of meat. This results in malnutrition in those living in the region¹³. The highest prevalence of anaemia has been observed in Ladakh, with 92.5%, 92.8% and 96.9% in children, women of reproductive age and adolescent girls respectively¹⁴.

Present scenario in Changthang

The present scenario in vegetable production in Changthang is completely different as today 30 different types of vegetables are grown with R&D as well as extension initiatives

by the highest altitude Krishi Vigyan Kendra (KVK) established in 2013 in the region for improving livelihood opportunities and to combat nutritional security among the tribal population. After conducting a baseline survey, the farmer's needs were assessed. Research areas were prioritized, and technologies were developed, assessed and refined according to the micro-farming situations of the region. Several extension methods like on-campus and off-campus training programmes, films, exposure visits, method demonstrations, front line demonstrations (FLDs) and on-farm trainings (OFTs) have been conducted to provide maximum benefit to farmers of this region. The impact of training programmes on protected cultivation is shown in Figure 3. Due to the benefits of the scientific methods of cultivation for improving the nutritional security of this region, farmers have been motivated to opt for such methods of cultivation through training, method demonstrations, providing technical know-how and distribution of improved seeds and seedlings. The defunct (unused) protected structures were made functional with suitable modifications. Regular inspection and monitoring were done throughout the growing season. Women were encouraged to various skill development training programmes on protected vegetable cultivation. Special events like breastfeeding and nutritional week were conducted in different villages with a special focus on improving the nutritive value of daily diets of woman. Several high-value crops like broccoli, Chinese cabbage, and Swiss chard under low tunnels have been newly introduced in this region, which was well accepted by the Changpas. Similarly, summer vegetables like cucurbits and solanaceous vegetables were successfully introduced in mud-type polyhouses.

Protected structures as a key factor to meet nutritional security among Changpas

To fulfil the aim and objective of combating nutritional security in the study region, various steps have been taken.

To supply quality seedlings to farmers of the Changthang

Nursery raising of vegetables under greenhouse conditions has a huge potential to fulfil the needs of this remote region. It can also help earn a good income to enhance the living standard of the farmers. Otherwise, the farmers totally depend on the lower (Leh) region for seedlings. The mortality rate of seedlings is high due to long-distance transportation and the lack of suitable varieties recommended for the region. Hamlets in the region are sparsely located, wherein villages are at a distance of 35–45 km from one another. Therefore, vegetable nursery sowing must be encouraged in every village during mid-April under greenhouse conditions for easy availability of quality seedlings. Simultaneously, the owner of the polyhouse can earn a good income through the sale of nursery seedlings.

To meet nutritional security through a balanced diet

Vegetables are known as protective foods and an essential source of micronutrients needed for a healthy body and mind. Under protected structures, all types of vegetables can be successfully grown, improving every household's nutritional security. To alleviate micronutrient deficiency, there is an urgent need to create awareness regarding nutrition gardens among farmers in order to grow fresh vegetables for daily consumption. An adult requires 500 g of vegetables, 100 g of fruits and 60 g of pulses for normal maintenance of health¹⁵, which is missing among the locals. In Ladakh, particularly in the Changthang region, the majority of the farmers buy vegetables from the markets at high prices to meet their requirements. These vegetables are loaded with pesticides and insecticides, which can cause health hazards. Therefore, setting up nutrition gardens is a significant step to mitigate these problems. Several studies by KVK Nyoma have shown that smallholder and farm women can play a key role in achieving nutritional security.

To empower Changpa tribal women through protected vegetable cultivation

Women, in general, play a major role in the agrarian community in Ladakh, ultimately leading to what scholars in this region deem the 'feminization of agriculture'^{16–21}. The Changpa tribal women must be encouraged to cultivate vegetables, which can be a source of income. In addition, the produce of this region is of high quality due to the organic farming system. Therefore, to improve their living standards and get recognition of their produce, mud or mud-brick polyhouses are required where different vegetables can be grown throughout the season. This will help generate income and uplift the tribals' standard of living.

Potential suitable protected structures for Changthang

Low tunnels

This is the most compatible and cheapest portable protected structure suitable for growing vegetables under Changthang

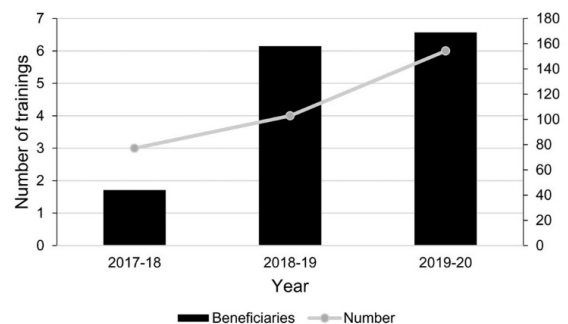


Figure 3. Training on protected cultivation and number of beneficiaries in Changthang (2017–2019).

Table 2. Potential vegetable crops recommended for the Changthang region under low tunnel during summer season (mid-May to September) (q/ha)

Crop	Recommended variety	Yield local practice (q/ha)	Yield improved practice (q/ha)
Chinese cabbage	Palampur green	151.09	352.06
Cauliflower	PSB-1	350	650
Cabbage	Mitra	266.67	833
Broccoli	Lucky	NA	350
Swiss chard	CITH Red & Green	200	428

**Figure 4.** Cultivation of cauliflower, broccoli and Swiss chard in low tunnel at 14,200 ft amsl in Tsaga village.

conditions at an altitude of 3400–4400 m amsl in summer. It protects from cold stress during night hours in the early growth stages of cole crops (Figure 4). For instance, temperature is a key factor in early growth and curd formation in cauliflower. Similarly, cabbage head size is found to considerably improve if grown in low tunnels along with the recommended genotype²². This technology has led to the successful introduction of broccoli in the Changthang highlands²³. Therefore, it is beneficial for growing cole and leafy vegetables in the region (Table 2)²⁴. The lower belt of Ladakh at 3000 m amsl is used for nursery raising and cucurbits cultivation. This structure is highly adopted by all types of farmers.

Mud-type polyhouse (double walled)

This dimension is (32 ft × 16 ft) made up of local bricks insulated with sawdust and plastered with mud on both sides is most suitable throughout the year. Most villagers own this type of greenhouse, but it remains unused due to the unavailability of quality polythene and a lack of technical know-how. Therefore, to make it functional, high-quality polythene (150 GSM) was provided, and demonstrations on cucurbit cultivation were given to the farmers.

Trench technology

This is an underground, low-cost, rectangular structure (10 ft × 6 ft × 2 ft :: $L \times W \times D$) in north–south orientation with stone walls on four sides. It is covered with a polyethylene sheet at the ground level during winter and is the first protected structure developed in Ladakh²⁵. This structure is suitable for growing crops in all four seasons in the

Leh region²⁶. Whereas in Changthang, it is suitable for nursery raising and summer crops like summer squash, cole crops and solanaceous vegetables. During peak winter, the crops experience freezing stress; therefore, they are mainly restricted to spring, summer and autumn.

Response of individual summer crops under mud-type polyhouse

Cucumber

This has been newly introduced under the greenhouse, and many varieties like JLG, SH-1, SH-2 and Gynoecious variety Aviva were evaluated. Among these, the variety Aviva performed well and recorded 1270 q/ha with a long harvest duration from mid-July to the first week of October (Figure 5). This crop is highly remunerative due to continuous production per plant. At present, the cucumber of Changthang is gaining popularity due to its distinct taste and quality. Long melon is also grown for use in salads due to its earliness and more fruits/plant, but being a new crop, it will take time to be accepted by the locals.

Cucurbit

This has set a new record in the farming system at an altitude of 4200 m amsl, where fruits like watermelon and muskmelon are growing well under greenhouse conditions. The watermelon varieties like Kalia and Rasdar are performing well, with an average fruit weight between 3 and 5 kg. Similarly, muskmelon var. Apsara is the best compared to other varieties (Figure 5). The average fruit weight ranges from 700 g to 1 kg with high TSS (8–10 brix). Other cucurbit crops like squash, bottle gourd and bush squash perform well, but acceptability among the locals is low due to their different food habits. Therefore, to popularize these crops, value addition or their use in local delicacies can be promoted.

Tomatoes

These can be early grown under open conditions at 10,500 ft amsl in the lower belt of Ladakh region using black mulch in summer. However, the scenario in Changthang is completely different. Here, most locals were reluctant to grow



Figure 5. Performance of summer vegetables in mud-type greenhouse under *Changthang* conditions at 14,000 ft amsl. *a*, Greenhouse mud wall, Mudh village; *b*, Cucumber variety Aviva; *c*, Muskmelon; *d*, watermelon (weight 7 kg); *e*, Bush squash (patty pan variety); *f*, Okra.

tomatoes even in the greenhouse due to short summers and a lack of technical know-how leading poor yield and quality. Therefore, various genotypes have been evaluated under greenhouse conditions in Changthang with proper staking and pruning to get quality fruits. Among the varieties, Millar (2.240 kg/plant) and Tapan (2.111 kg/plant) performed well.

Capsicum

This is emerging as a high-value crop in Ladakh under greenhouses conditions²⁷. Its cultivation at 4200 m amsl is another milestone in Changthang. Nine varieties collected from different sources have been evaluated under greenhouse conditions, and an average yield per plant of 1.309 kg was recorded in hybrid Koti, followed by 1.120 kg in Solan Bharpur. The demand for capsicum is rising now with more awareness. Its cultivation will bring additional revenue to the farming community of this region. Likewise, other solanaceous crops like brinjal as also perform well in the protected structures.

Winter production in mud-type protected structures

The freezing stress in open fields was observed in the last week of September in the study region, which is at least one month earlier compared to other regions of Ladakh. The khuls freeze, thus hampering the irrigation system. There-

fore, greenhouse cultivation is the only solution for fresh vegetables during the lean winter months. Several leafy vegetables have been grown under greenhouse conditions to encourage winter cultivation. Crops like Siberian kale, kale-Khanyari, Chinese cabbage, Swiss chard and lettuce are introduced for winter cultivation. During peak winter, the growth process is stunted and freezing injury is common²⁸. Among leafy vegetables, Swiss chard performs well, followed by Chinese cabbage. Therefore, to boost fresh vegetable production in winter, cultivation of the recommended crops and varieties under protected structures in Changthang plays a key role in achieving nutritional security.

Conclusion

Locals have a positive attitude toward the importance of protected cultivation as a self-sustainable technology and nutritionally secure. It is the only climate-resilient technology that will be a boon for the study region despite extreme climatic conditions and to fulfil the consumption requirements and maintain a healthy diet. Due to the nutritional power of vegetables, the area under protected cultivation can also be expanded into adjoining hamlets. The produce from this cold arid region will be unique and distinct due to the usage of organic inputs. Market-oriented vegetables not only provide business opportunities for the youth but also help small farmers overcome external risks and enhance their living standards. Through intervention, agro-climatic risk will be reduced, and crop duration will be extended.

The demand for local produce will grow, and proper marketing channels will also be developed. A major impact will be seen in the socio-economic, health and overall development of the society.

The cropping season is only for 3–4 months in open field conditions, but climate-resilient technologies like protected structures (low tunnel, trench, mud-wall greenhouse) are a boon for the study region, as they make it possible to grow more than 30 types of vegetables (cole, solanaceous, bulbs, cucurbits, leafy vegetables). This will not only extend the cropping period but also enhance nutritional security. Hence, these technologies have immense scope to increase farmers' income and play an important role in uplifting the rural livelihood of cold arid Ladakh, thus combating nutritional deficiency among the tribal communities.

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