P-ISSN: 2618-0723
E-ISSN: 2618-0731

NAAS Rating: 5.04
www.extensionjournal.com

International Journal of Agriculture Extension and Social Development

Volume 8; Issue 2; February 2025; Page No. 332-336

Received: 10-12-2024
Accepted: 16-01-2025

Indexed Journal
Peer Reviewed Journal

Low cost sustainable technology for winter vegetable cultivation in lower belt of UT Ladakh

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DOI: https://www.doi.org/10.33545/26180723.2025.v8.i2e.1656

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Abstract

Ladakh, a cold arid region, faces severe challenges in meeting its nutritional demands during the winter months due to extreme climatic conditions and the region's landlocked nature. Traditional methods, such as storing summer produce and relying on air-lifted supplies, are insufficient and economically unsustainable. This study aimed to explore the potential of low-cost, portable technologies for winter vegetable cultivation in the lower belt of Ladakh, particularly the village of Garghardho in Kargil district near the indo pak border, where moderate winters and longer photoperiods present unique opportunities.

The investigation, conducted during the winters of 2022-23 and 2023-24, introduced cold-tolerant vegetable species, including Swiss chard, Chinese cabbage, pakchoi, and kale, grown under refined low-cost structures such as low tunnels made from thick fiber wires and UV-stabilized polyethylene films. Black polyethylene mulch was used to conserve soil moisture and regulate temperature. Demonstration trials across multiple farmer fields showcased significant success, with Swiss chard yielding 5.89 kg/m² and Chinese cabbage 5.20 kg/m² during peak winter months. The first harvest was achieved within 29 days of transplanting, extending the growing season and ensuring consistent yields.

This study marks a first-of-its-kind approach in Ladakh, demonstrating that low-cost technologies can be a viable alternative to high-tech greenhouses for winter vegetable production. The findings highlight the economic and agricultural potential of utilizing low-cost structures to enhance food security and improve livelihoods in the region, making winter vegetable cultivation accessible to smallholder farmers.

Keywords: Ladakh, cold arid region, winter vegetable cultivation, food security

Introduction

Union Territory of Ladakh is a cold arid region characterized by extreme temperature variations, low precipitation mostly in the form of snow and high wind velocity. High altitude and harsh climatic conditions are the basic environmental challenges while meeting the nutritional requirements for maintaining highest level of mental and physical fitness (Angmo *et al*, 2017) [1] Providing essential nutritional support to people in high altitude are best taken from resources available locally as timely supply of fresh vegetables from low land is not always possible as the region remains landlocked for six months due to heavy deposition of snow on the road-passes which connects Ladakh to the main land of India. Air-lifting of the fresh vegetables results in heavy expenditure which is not affordable for the people. Farmers here in Ladakh construct vegetable cellars and store the summer produce tuber and root crops underground and they take them out for consumption in winter along with most of the people in the region consume meat pulses and dairy products. Therefore meeting the requirement of fresh vegetables for the local populace of the remote mountain areas especially during winter months is a formidable challenge. The temperature drops down to -30 C in winter in upper belts but in few villages of lower belt in the Aryan valley snow will not deposit for longer time and winter are mild. Significant progress has been made since 1960s in promoting vegetable cultivation in Ladakh by different research institutes. Major focus has been diverted on growing summer vegetables, leafy vegetables under greenhouse cultivation during winter and early raising of vegetable seedlings (Stobdan *et al*. 2017) [2]. Due to high initial cost and its maintenance the green house coverage area is very less in the region particularly in villages. The moderate climate of Gargardo village of Batalik region and adjoining areas has ensured early sprouting of vegetables under mulch. This practice gave the idea to scientist of KVK that the region has comparatively better climate during winter that can be harnessed for winter vegetable production. Simultaneously low cost protected structures like low tunnels/black polythene mulch can easily be afforded by the majority of population and can be a successful tool to cover the region for winter vegetables. On the other hand the region is well covered with apricot plantations and winter skeleton of these trees permit sufficient sun light during winter which is otherwise not available in active season. Thus the main aim of the present study is to identify the potential of lower belt of Ladakh as a winter vegetable hotspot with the introduction of low temperature tolerant varieties and low cost vegetable

cultivation technologies, low tunnel and mulching with some refinement and the viability of the same in the area.

Refinement of Low-Cost Technology

The present investigation was conducted during the winter season of 2022-23 in the farmer's fields of Village Garghardho, District Kargil, Union Territory of Ladakh. The study aimed to evaluate the performance of seven promising cold-tolerant vegetable species under refined low-cost technologies tailored for winter vegetable cultivation in the region.

Three types of low tunnel structures were developed using different materials to optimize the microclimate and ensure crop survival under extreme winter conditions. The materials used for the structures included: Polypropylene pipes, Iron wire and thick fiber wire. Additionally, a black polyethylene surface mulch (70 GSM) was employed to conserve soil moisture and regulate soil temperature. UV-stabilized polyethylene films (150 GSM) were used either as standalone covers or in combination with row covers to provide additional insulation against freezing temperatures. Details of these materials and their specifications are presented in Table 1. And Fig 1.

Figure 1: A) Semi high tunnel and vegetables under refined low tunnel B) low tunnel using polyproplylene pipes C) I. Low tunnel using thick fiber wire ii) Low tunnel using prefabricated iron wire.

Standardization of Agro-Techniques

Source of seeds

Low temperature tolerant leafy vegetables were introduce from aboard and also Indian Agriculture Research Institute, Katrain, HP (listed in Table. No.2). The selected vegetable varieties included different kale, Swiss chard genotypes and Chinese cabbage which were initially evaluated for performance in a greenhouse at the KVK campus during the first year (2021-22). The seeds of promising genotypes were multiplied in bulk to ensure their availability for subsequent trials.

Nursery Raising

Cold tolerant Vegetables nursery were raised under protected structure at KVK Campus in the month of 2nd week of September as the temperature outside during the night were not favourable for the seeds to germinate and grow. The seedlings were ready by 2nd week of October (Fig.2) and taken to the experimental area for the demonstration trail.

Fig 2: Healthy nursery of winter vegetable in October

Laying of Demonstration Trials

Demonstration trials were conducted at 10 locations during the 2022-23 winter season and expanded to 25 locations in 2023-24. The trials were conducted in the farmers' fields, and the transplanted vegetables were grown under the refined low-cost structures. Standardized beds of 25 × 8 feet were prepared at each location. Beds were enriched with farmyard manure (FYM), biofertilizers, and covered with black polyethylene mulch (70 GSM). Holes were made in the mulch at designated spacings based on the crop requirements (Table 2). Cold-tolerant vegetables such as Swiss chard, Chinese cabbage, pakchoi, and kale were transplanted into the mulch beds during the second week of October and again in the second week of November and the fibre wire was installed at 2 feet distance and covered with 150 GSM UV-stabilized polyethylene films (Fig.3).

Fig 3: A) Ploughing and leveling B) Laying of mulch and making hole in mulch at proper spacing C) Transplanting and watering D) making low cost low tunnel frame manually using thread and wireE) & F) Covering with UV film

Results and discussion

Refinement of Low-Cost Protected Structures for Winter Vegetable Cultivation

In the present study, very low-cost and portable protected structures were developed and refined to facilitate vegetable cultivation during the harsh winter conditions of Ladakh. Among the different materials for low cost structure Table 2 and Fig.1. Thick fibre wire was selected due to its low cost and flexible nature. The structures incorporated thick fibre wires as frame, UV-stabilized polyethylene film (150 GSM) and non-woven fabric as covering materials. These coverings provided insulation, effectively protecting crops from sub-zero temperatures. Additionally, high-GSM black polyethylene mulch (70 GSM) was utilized to prevent soil frost and maintain favorable soil conditions for crop growth. This innovation was implemented in the lower belt of Ladakh, specifically in the village of Ghargardho, strategically located near the India-Pakistan border.

Table 1: Comparative cost of different low tunnel structure (25*8feet)

S. No.	Materials used	Total Cost of structure	Remarks
1	Thick fiber wire	2120	Durable, portable, easily dismantle, low cost, flexible and temperature regulation
2	Prefabricated iron wire	7000	Accommodate space to carry, Rusting, bend easily, costlier, not flexible
3	Polypropylene pipes	5000	Not recommended, costly, not flexible
4	Semi high tunnel	17500	Very costly, need space to accommodate, cannot maintain temperature in winter

Novelty of the Approach

Traditionally, vegetable cultivation in Ladakh during winter has been confined to high-tech greenhouses. However, no previous reports or documented attempts exist on utilizing low-tunnel structures for vegetable cultivation in the region during winter however the same technology has been used for cultivation of vegetable in summer at high altitude of Ladakh (Spaldon *et al.* 2021) [4] and (Angmo *et al.* 2017) [1]. The present study marks the first successful attempt to cultivate vegetables during harsh winter in such structures, demonstrating their potential to extend the growing season and enhance food security for the farmers with low land holdings.

Performance Analysis of Vegetables Transplanted in Low-Tunnel Structures

Vegetable seedlings were transplanted in October and November under the refined low-cost structures. A comparative analysis revealed that October transplantations outperformed those planted in November in terms of consistent yield, adaptability, and growth parameters. The favorable environmental conditions provided by the refined structures during October allowed for better establishment and robust growth of the crops.

Yield and Economic Performance

The study recorded exceptional yield outcomes during the peak winter season, showcasing the effectiveness of the refined low-cost technology. The first cutting was achieved just 29 days after transplantation, by the end of November 2022. Subsequent harvests were conducted continuously from December 2022 to the end of March 2023, demonstrating the adaptability of the introduced crops to winter conditions. Among the introduced vegetable crops evaluated during the study, Swiss Chard (Burpee Red) exhibited the highest yield, with an impressive production of 5.89 kg per square meter under the refined low-cost protected structures. This was followed by Chinese Cabbage, which yielded 5.20 kg per square meter (Fig 4). The early and high yield was obtained in cabbage under low tunnel in Kargil by Mehdi *et al.* 2014 [3] as compared to open field condition during summer.

These yields were achieved during the peak winter months when conventional outdoor farming is not feasible in Ladakh due to extreme cold. This achievement represents a first-of-its-kind success in the area, significantly contributing to local agricultural practices except under high tech-green house (Fig. 3). The yield potential of the introduced vegetable varieties, as observed during the study, is detailed in Table 2 and visualized in Fig. 5. In Ladakh during winter vegetables can only be grown under high tech and Ladakhi type of green house with polycarbonate sheet as cladding materials. The technology needs high initial cost and maintenance and permanent area due to which the popularity and promotion is restricted despite of huge subsidies on its construction.

Table 2: Yield performance of introduced vegetables

Vegetable Crop	Mean/Average Yield/m2 (Kg)	Number of harvest	Source of seeds
Swiss Chard (Bhurpee Red)	5.89	3	Hudson Valley seed company USA
Chinese Cabbage	5.20	1	hybrid
Kale (Pusa 64)	5.16	3	IARI, Katrain, HP, India
Kale (Lacinato Kale)	5.00	3	Hudson Valley seed company, USA
Kale (Curly Kale)	4.00	3	Hudson Valley seed company, USA
Kale (Dwarf Kale)	3.25	2	Hudson Valley seed company, USA
Kale (Red Russain)	3.40	3	Hudson Valley seed company, USA

Fig 4: A) Performace during November 2022, B) Low tunnel covered with snow in December, 2022 C) Vegetables under low tunnel after removing snow in decmber 2022, D) During Jan, 2023 E) During Feb, 2023, F&G) During March, 2023 H) Farmer exposure visit in the area

Comparison with Farmer Practices: The results from this study demonstrate a stark contrast to the traditional farming practices in the region. Typically, farmers grow turnip greens in high-cost greenhouses, with transplantation beginning in February. These greenhouses require substantial investment and maintenance costs, limiting their accessibility for smallholder farmers. In contrast the low-cost protected structures enabled an earlier planting season (October-November), extending the harvesting period from November to March with low cost of production with an irrigation at an interval of 15 days (Fig 6). The profitability of kale and Swiss chard under the low-cost system significantly exceeded that of turnip greens in high-tech greenhouses, offering a more cost-effective and sustainable alternative for winter vegetable production.

Mass Demonstration of the Technology

To promote the adoption of low-cost protected structures and standardized agro-techniques for off-season vegetable cultivation, large-scale demonstrations were conducted in the farmers' fields across the study region (Fig. 5). These demonstrations served as a practical platform to create awareness among farmers about the potential of growing high-value vegetables during the harsh winter months using cost-effective and innovative methods.

Fig 5: Steps wise demonstration of the technology A) Plouging and leveling of field, B) Bed preparation and laying of Black Mulch, C) Hole making at recommended spacing, D) Transplanting of different vegetables, E) instaltion of fibre stick and Covering with row cover and UV film 150 GSM

Fig 6: Performance of different Vegetables during Winter under snow (November, 2023 to March 2024) A) November B) December, C) January D) February

Conclusion

This study demonstrates the successful implementation of low-cost, refined low-tunnel technologies for winter vegetable cultivation in Ladakh's lower belt. Using cold-tolerant varieties and materials like thick fiber wire and UV-stabilized films, significant yields were achieved, surpassing traditional methods. This approach offers a viable, affordable alternative to high-tech greenhouses, enhancing food security and economic opportunities for smallholder farmers in the region.

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