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# Growing Cauliflower in Winter under Passive Solar Greenhouse in Trans-Himalayan Ladakh, India

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**ABSTRACT**

Traditionally cauliflower is not grown during winter months in the trans-Himalayan Ladakh region due to sub-zero degree celsius at night. Accordingly, the feasibility of growing cauliflower, a temperature-sensitive crop, was studied during winter months in a passive solar greenhouse in the high altitude (elevation 3340 m) trans-Himalayan Ladakh region. Studies were conducted during 2017-2020 with three commercial varieties. Curd was formed in all the varieties despite the temperature extremes (0.0±1.6 to 39.5±0.9 ºC) in the greenhouse. Harvesting was done in the month of February. The mean marketable curd weight ranged from 258±113 to 743±62 g depending on variety and year, which suggested that cauliflower can be successfully grown during winter months in the trans-Himalaya. However, the marketable curd weight was significantly lower as compared to the yield potential of the varieties. High temperature inside the greenhouse resulted in the occurrence of fuzziness, and it ranged from 0-35% of the harvested curd depending on the year and variety. Fuzziness was not observed in cv Shentha while 10.4-35% of cv Amazing exhibited fuzziness.

**Keywords:** *Brassica oleracea*; Diurnal temperature variation; Protected cultivation; Passive solar greenhouse; High altitude agriculture

## 1. INTRODUCTION

The high altitude Ladakh region is characterised by a rugged topography at an average altitude of over 3000 m above sea level. The region is characterised by low precipitation, extreme temperature variations, thin atmosphere with high UV-radiation, high wind velocity, sparse plant density, and fragile ecosystem. The temperature drops down to -30 ºC in winter season. Long harsh winters reduce the cropping season to just four to five months in a year. The region remains cut-off from November-April due to heavy snowfall. The locally grown fresh vegetables are available only during summer months, and therefore, there are seasonal differences in intake of fresh vegetables[1]. The accessibility to fresh vegetables decreases significantly during winter season, which has resulted in an unbalanced diet. Low dietary diversity and seasonal shortfall lead to micronutrient deficiencies, a phenomenon that has been described as 'hidden hunger'[2].

Self-sufficiency in food is an important issue for the region. Filling the gap between the demand and supply of fresh vegetables is a difficult task. During winter months a limited quantity of fresh vegetables is brought in by air from Chandigarh or Delhi paying as much as Rs 80-110 per kg just for the air freight. Therefore, fresh vegetables are 2.7-fold costlier in Ladakh as compared to metropolitan city Delhi[3]. Meeting the increasing demand of fresh vegetables at an reasonable price in Ladakh is a formidable challenge. A large number of passive solar greenhouse structures have been designed and tested in the region to produce fresh vegetables during winter months. Greenhouse cultivation has become popular, and almost every household in Ladakh owns a greenhouse. However, the temperature inside the greenhouse during winter months often drops to sub-zero degree Celsius at night, which limits growing of only freeze tolerant leafy vegetables such as beet leaf, spinach, coriander and lettuce. Therefore, there is a need for improvised passive solar greenhouse designs to grow a variety of crops other than the leafy vegetables during winter months[3].

Cauliflower (*Brassica oleracea* var. *botrytis*) is a temperature sensitive crop grown for its immature inflorescence called curd. Its growth periods (germination to transplanting, transplanting to curd initiation and curd initiation to harvest) respond differently to environmental variables[4-5]. It is highly sensitive to growing conditions and requires more attention than broccoli, cabbage and other close relatives and thus regarded as the aristocrat of the Cruciferae family[6]. Cauliflower is a popular summer crop in Ladakh. The nursery are transplanted in early May and the crop reaches harvestable stage in July-September[1]. However, during winter months there is an acute scarcity of cauliflower in the region. In February 2019 the retail price of cauliflower was Rs 110 per kg in Leh town as compared to Rs 28-30 per kg in Delhi due to high air cargo charges[3]. Accordingly, the purpose of this study was to determine the

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feasibility of growing cauliflower, which is a temperature sensitive crop, during winter months in an improvised passive solar greenhouse in the trans-Himalayan Ladakh region.

## 2. MATERIALS AND METHODS

### 2.1 Study Site and Growth Conditions

Cauliflower was grown in an improvised passive solar greenhouse (IP Greenhouse) at the Defence Institute of High Altitude Research in trans-Himalayan Ladakh, India (elevation 3340 m, 34°08.2'N; 77°34.3'E). IP Greenhouse is a medium sized (90'×27'×9'; L×W×H) passive solar greenhouses in east-west orientation having cement plastered stone wall on three sides (east and west wall: 1'6" thick; north wall: 2' thick). It is covered with a clear UV-stabilised 16-mm triple layer polycarbonate panel on the south-facing side. A portion of the east and west walls are covered with the cladding material (i.e. at 4' height). It has a sloped (to the north) wooden roof which is covered with a layer of straw and soil for insulation on the north side of the greenhouse (Fig. 1). Temperature is maintained with manually operated ventilators on the south-facing and the west frame. No supplementary lighting and heating were provided, and the structure was not covered with any thermal blanket, even in the peak winter. Relative humidity and temperature were recorded daily with a hygro-thermometer (445702, Extech Instruments). PAR was recorded with a radiometer (PMA2100, Solar Light) with a PAR detector (PMA2132). The weather and microclimate data of the greenhouse are shown in Table 1.


**Figure 1. Cauliflower crop inside the greenhouse in the month of December.**

### 2.2 Experimental Design

The experiment was conducted during 2017-2020 with three commercial varieties- Shentha, WS-909 and Amazing. Randomised block experimental design was used with three replications. Each replication plot was 2.8 × 1.7 m in size. Each replicate consisted of 24 plants spaced at 35×35 cm. Farmyard manure (3.4 kg per $m^2$) was applied at the time of field preparation. No weedicide, fungicide and pesticide were used throughout the growing season. Irrigation was done by

**Table 1. Microclimate inside the improvised passive solar greenhouse during winter season in trans-Himalayan Ladakh region**

| Year | Month | Temperature in open field (ºC) | | Temperature inside greenhouse (ºC) | | Relative humidity inside greenhouse (%) | | PAR at 12 noon inside greenhouse (µmol/$m^2$s) |
|---|---|---|---|---|---|---|---|---|
| | | Max | Min | Max | Min | Max | Min | |
| 2017-18 | October | 12.5±2.8 | -3.9±1.5 | 38.8±2.7 | 10.4±0.9 | 87.4±3.5 | 22.1±4.0 | 833.2±83.5 |
| | November | 7.9±3.8 | -7.7±2.9 | 33.0±6.2 | 5.3±2.5 | 90.5±5.7 | 34.8±17.3 | 458.6±268.4 |
| | December | 3.6±1.8 | -10.8±2.4 | 26.8±8.3 | 3.1±1.1 | 96.5±2.5 | 62.5±15.9 | 484.3±239.1 |
| | January | 2.2±2.4 | -13.6±2.7 | 30.3±4.2 | 1.8±1.1 | 96.0±2.4 | 57.9±7.5 | 570.0±89.5 |
| | February | 4.1±2.4 | -8.8±2.9 | 30.0±5.6 | 4.1±2.0 | 95.8±1.5 | 50.3±10.1 | 312.6±151.2 |
| | **Mean** | **6.1±4.2** | **-9.0±3.6** | **31.8±4.5** | **4.9±3.3** | **93.2±4.1** | **45.5±16.8** | **531.7±192.4** |
| 2018-19 | October | 12.0±2.8 | -1.6±3.2 | 39.5±0.9 | 10.5±2.3 | 92.1±12.6 | 30.9±8.6 | 652.1±263.4 |
| | November | 7.4±2.2 | -6.5±2.4 | 31.6±6.6 | 7.2±2.1 | 95.6±5.2 | 50.4±7.7 | 308.2±49.6 |
| | December | 2.7±3.0 | -12.7±3.2 | 28.3±5.1 | 1.8±1.3 | 97.9±1.3 | 56.7±5.2 | 224.6±103.3 |
| | January | -0.9±2.5 | -12.9±2.8 | 27±4.8 | 0.2±1.7 | 98.4±0.8 | 64.5±9.2 | 234.9±126.6 |
| | February | 0.5±2.4 | -9.1±4.7 | 24.8±7 | 2.8±1.7 | 97.2±1.8 | 59.5±19.2 | 296.4±204.7 |
| | **Mean** | **4.3±2.6** | **-8.6±3.3** | **30±4.9** | **4.5±1.8** | **96.2±4.3** | **52.4±10.1** | **343.3±149.7** |
| 2019-20 | October | 14.2±2.8 | -0.8±3.1 | 39.0±4.8 | 12.0±1.8 | 91.3±4.7 | 28.0±5.8 | 471.6±147.9 |
| | November | 7.9±3.3 | -4.9±3.2 | 32.1±6.2 | 7.4±2.1 | 94.0±5.7 | 44.6±15.7 | 463.6±116.5 |
| | December | 0.0±2.4 | -12.9±4.1 | 26.1±8.3 | 2.3±1.8 | 95.9±2.5 | 60.1±14.5 | 258.2±173.9 |
| | January | -2.9±1.1 | -14.1±3.0 | 18.9±7.1 | 0.0±1.6 | 95.2±2.1 | 69.2±13.3 | 260.4±25.9 |
| | February | 3.6±3.5 | -11.6±3.9 | 32.1±4.4 | 4.7±2.5 | 89.6±3.8 | 46.7±12.0 | 370.9±154.3 |
| | **Mean** | **4.6±2.6** | **-8.9±3.3** | **29.6±6.2** | **5.3±2.0** | **92.1±3.8** | **49.7±12.3** | **364.9±123.7** |

flooding at one week interval during initial plant establishment time followed by three weeks interval at later stages. Seedlings raised in a passive solar greenhouse were transplanted manually on 16 October 2017, 01 October 2018, 4 October 2019. Weeding was done twice during the growing season.

### 2.3 Growth and Yield Attributes

Data were recorded on the number of leaves, leaf area, relative growth rate (RGR), leaf weight ratio (LWR), specific leaf area (SLA), net assimilation rate (NAR) and chlorophyll content at 0-30, 30-60 and 60-90 days after transplanting (DAT). RGR, SLA, LWR and NAR were determined as described by Hunt[7], *et al*. Curd weight at fresh market maturity were recorded three times in a season. All curds were trimmed to market standards and weighed. At harvest, the plants were assessed for curd quality defects and the number of curds with symptoms of physiological disorders was determined.

### 2.4 Statistical Analysis

All the experiments were performed in triplicates. The experimental results were expressed as mean ± standard deviation (SD) using statistical analysis with SPSS (Statistical Program for Social Sciences, SPSS Corporation, Chicago, Illinois, USA). One way analysis of variance (ANOVA) and post hoc analysis with 2-sided Tukey's HSD at $p \leq 0.05$ level were performed.

## 3. RESULTS AND DISCUSSION

### 3.1 Growth and Yield Attributes

The growth of cauliflower plants was determined by their RGR. The RGR describes the rate of increase in plant mass per unit plant mass already present. The RGR followed a decreasing trend with time in all three varieties, with few exceptions (Table 2). The mean RGR at 0-30, 30-60, and 60-90 DAT was 87.1±24.2, 77.5±10.0 and 35.6±2.4 mg $g^{-1}$ $d^{-1}$,

**Table 2. Growth parameters of three commercial varieties harvested in 2017-18 winter seasons in trans-Himalayan Ladakh**

| Parameters | DAT | Shentha | WS-909 | Amazing | Mean of three varieties |
|---|---|---|---|---|---|
| Number of leaf | 30 | $7.0\pm0.9_{A}^{a}$ | $7.2\pm0.8_{A}^{a}$ | $6.7\pm1.2_{A}^{a}$ | $7.0\pm0.3_{A}$ |
| | 60 | $10.2\pm1.2_{B}^{a}$ | $9.5\pm0.5_{B}^{a}$ | $9.8\pm0.8_{B}^{a}$ | $9.8\pm0.4_{B}$ |
| | 90 | $14.2\pm1.5_{C}^{b}$ | $13.3\pm0.8_{C}^{b}$ | $11.5\pm0.8_{C}^{a}$ | $13.0\pm1.4_{C}$ |
| Leaf area | 30 | $524.8\pm23.8_{X}^{c}$ | $347.1\pm31.7_{X}^{b}$ | $233.8\pm7.6_{X}^{a}$ | $368.6\pm146.7_{X}$ |
| | 60 | $1757.1\pm22.2_{Y}^{c}$ | $1405.1\pm25.5_{Y}^{b}$ | $1243.9\pm12.7_{Y}^{a}$ | $1468.7\pm262.4_{Y}$ |
| | 90 | $3234.5\pm202.7_{Z}^{b}$ | $2968.1\pm313.5_{Z}^{b}$ | $2087.9\pm476.2_{Z}^{a}$ | $2763.5\pm600.1_{Z}$ |
| RGR | 0-30 | $108.1\pm8.3_{C}^{b}$ | $92.6\pm5.9_{B}^{ab}$ | $60.7\pm9.8_{B}^{a}$ | $87.1\pm24.2_{B}$ |
| | 30-60 | $71.2\pm2.4_{B}^{a}$ | $72.3\pm3.5_{AB}^{ab}$ | $89.0\pm11.0_{C}^{b}$ | $77.5\pm10.0_{B}$ |
| | 60-90 | $36.4\pm4.2_{A}^{a}$ | $37.5\pm3.6_{A}^{a}$ | $32.9\pm5.5_{A}^{a}$ | $35.6\pm2.4_{A}$ |
| SLA | 0-30 | $197.8\pm48.8_{Y}^{a}$ | $185.8\pm18.1_{Y}^{a}$ | $230.5\pm24.3_{Y}^{a}$ | $204.7\pm23.1_{Y}$ |
| | 30-60 | $80.0\pm9.0_{X}^{a}$ | $78.0\pm1.7_{X}^{a}$ | $88.2\pm17.0_{X}^{a}$ | $82.1\pm5.4_{X}$ |
| | 60-90 | $84.3\pm8.4_{X}^{a}$ | $94.6\pm8.9_{X}^{a}$ | $103.1\pm17.9_{X}^{a}$ | $94.0\pm9.4_{X}$ |
| LWR | 0-30 | $0.82\pm0.04_{B}^{b}$ | $0.71\pm0.01_{B}^{a}$ | $0.78\pm0.01_{B}^{b}$ | $0.77\pm0.06_{B}$ |
| | 30-60 | $0.79\pm0.02_{B}^{a}$ | $0.78\pm0.08_{B}^{a}$ | $0.76\pm0.01_{B}^{a}$ | $0.78\pm0.02_{B}$ |
| | 60-90 | $0.47\pm0.06_{A}^{a}$ | $0.44\pm0.01_{A}^{a}$ | $0.40\pm0.03_{A}^{a}$ | $0.44\pm0.04_{A}$ |
| LAR | 0-30 | $161.1\pm31.9_{Y}^{a}$ | $131.9\pm15.0_{Y}^{a}$ | $179.9\pm22.0_{Y}^{a}$ | $157.6\pm24.2_{Y}$ |
| | 30-60 | $63.2\pm5.9_{X}^{a}$ | $61.2\pm7.2_{X}^{a}$ | $66.7\pm12.4_{X}^{a}$ | $63.7\pm2.8_{X}$ |
| | 60-90 | $38.8\pm0.7_{X}^{a}$ | $41.8\pm4.7_{X}^{a}$ | $41.3\pm9.9_{X}^{a}$ | $40.6\pm1.6_{X}$ |
| NAR | 0-30 | $0.70\pm0.22_{A}^{a}$ | $0.69\pm0.12_{A}^{a}$ | $0.34\pm0.09_{A}^{a}$ | $0.58\pm0.21_{A}$ |
| | 30-60 | $1.13\pm0.07_{B}^{a}$ | $1.19\pm0.08_{B}^{a}$ | $1.38\pm0.42_{B}^{a}$ | $1.23\pm0.13_{B}$ |
| | 60-90 | $0.94\pm0.09_{AB}^{b}$ | $0.91\pm0.19_{AB}^{ab}$ | $0.81\pm0.07_{AB}^{a}$ | $0.89\pm0.07_{AB}$ |
| Chlorophyll content (SPAD) | 30 | $46.5\pm5.5_{X}^{a}$ | $45.0\pm2.3_{X}^{a}$ | $47.1\pm9.0_{X}^{a}$ | $46.2\pm1.1_{X}$ |
| | 60 | $48.4\pm2.6_{X}^{a}$ | $50.0\pm4.3_{X}^{a}$ | $48.9\pm5.4_{X}^{a}$ | $49.1\pm0.8_{X}$ |
| | 90 | $51.1\pm5.7_{X}^{a}$ | $46.4\pm4.4_{X}^{a}$ | $51.2\pm6.9_{X}^{a}$ | $49.6\pm2.7_{X}$ |

Values represented as mean ± SD;
For each row different lowercase letters indicate significantly different at $p \leq 0.05$ as measured by Tukey's test between varieties
For each column, different uppercase letters indicate significantly different at $p \leq 0.05$, as measured by Tukey's within a variety and mean value at different days after transplantation
DAT: days after transplanting; LA: leaf area ($cm^2$); RGR: relative growth rate (mg $g^{-1}$ $d^{-1}$); SLA: specific leaf area ($cm^2g^{-1}$); LWR: leaf weight ratio (g / $g^{-1}$); LAR: leaf area ratio ($cm^{-2}$ $g^{-1}$); NAR: net assimilation rate (mg $cm^{-2}$ $d^{-1}$)

respectively. Significantly high RGR at initial growth stage (0-30 DAT) may be due to more favourable temperature during the period. SLA, which reflects the expected return on previously captured resources, followed a decreasing and then increasing trend with time as the leaf matures. Lower SLA suggested that retention of the captured resource is a higher priority at later growth stages. The NAR, which refers to the net efficiency of plant photosynthesis, increased and then decreased with growing stages in all three varieties. The mean NAR increased from 0.58±0.21 at 0-30 DAT to 1.23±0.13 mg $cm^{-2}$ $d^{-1}$ at 30-60 DAT and then again decreased to 0.89±0.07 mg $cm^{-2}$ $d^{-1}$ at 60-90 DAT. The significant varietal difference in NAR was observed among the three commercial varieties.

Curd was formed in all three varieties despite the temperature extremes in the greenhouse. The monthly minimum temperature inside the greenhouse ranged from 1.8±1.1-10.4±0.9 ºC in 2017-18; 0.2±1.7-10.5±2.3 ºC in 2018-19; 0.0±1.6-12.0±1.8 ºC in 2019-20 growing period. Similarly, the monthly maximum temperature ranged from 26.8±8.3-38.8±2.7 ºC in 2017-18; 24.8±7-39.5±0.9 ºC in 2018-19; 18.9±7.1-39.0±4.8 ºC in 2019-20 growing period. Normal curds are formed at 10-25 ºC[8]. Curd formation is reported to be very sensitive to temperature extremes. High temperatures do not favour curd formation[4,9]. No curd is formed at 25 ºC or above[9,10]. However, in the present study normal curd were formed despite above 25 ºC day temperature on most of the days (Fig. 2). Normal curd formation maybe because the low temperature effect accumulates in the plants and curds are formed when the chilling requirement is satisfied[11].

Harvesting was carried out on 4-15 February 2018, 30 January-22 February 2019, and 6-25 February 2020. The mean marketable curd weight of the variety Shentha, WS-909 and Amazing was 0.60±0.13, 0.54±0.14 and 0.33±0.13 kg, respectively during the three year study period (Table 3).

**Figure 2. Normal curds formed inside the greenhouse in the month of February.**

A significant varietal difference in marketable curd weight was observed. The yield also differed significantly in different years. The marketable curd weight was significantly low as compared to the yield potential of the varieties. The yield potential of variety Amazing is 1-1.5 kg and that of Shentha is 1.5-2 kg. Low curd weight may be because of high day temperature inside the greenhouse. High temperature above 22.5-25 ºC is known to decrease curd apex diameter and weight[9,12]. Wheeler[13], *et al.* also reported that warmer temperatures reduce the total biomass at the last harvest. Dry weight reduction of 6 percent for every 1 °C rise in temperature has been reported. Delay in harvesting resulted in loose or yellow curd formation due to high temperature. Gopalakrishnan[12] also stated that at temperatures above 25 °C the curd forms are small, loose or yellow.

**Table 3. Cauliflower yield in three winter seasons in trans-Himalayan Ladakh**

| Variety | Harvest month and year | Yield parameters | | | | | Fuzziness (%) |
|---|---|---|---|---|---|---|---|
| | | Curd diameter (cm) | Gross curd weight (g) | Marketable curd weight (g) | Net curd weight (g) | Harvest index (%) | |
| Shentha | Feb 2018 | $20.4\pm0.2_{A}^{b}$ | $1306\pm150.8_{B}^{a}$ | $743.0\pm62.0_{E}^{b}$ | $638\pm84_{A}^{a}$ | $38.2\pm13.0_{A}^{a}$ | 0 |
| | Feb 2019 | $15.6\pm0.9_{A}^{a}$ | $1060\pm217_{AB}^{a}$ | $536\pm182_{CDE}^{ab}$ | $417\pm84_{A}^{a}$ | $35.2\pm3.3_{A}^{a}$ | 0 |
| | Feb 2020 | $17.8\pm0.4_{A}^{ab}$ | $935\pm498_{AB}^{a}$ | $508\pm163_{BCDE}^{a}$ | $437\pm120_{A}^{a}$ | $37.5\pm1.1_{A}^{a}$ | 0 |
| | **Mean** | **17.9±2.4** | **1100.3±188.8** | **595.7±128.4** | **497.3±122.2** | **37.0±1.6** | **0** |
| WS-909 | Feb 2018 | $20.4\pm0.2_{A}^{z}$ | $1106.3\pm63.1_{AB}^{x}$ | $639\pm76.7_{DE}^{y}$ | $502\pm64.1_{A}^{y}$ | $34.3\pm12.3_{A}^{x}$ | $14.5\pm2.5_{B}^{ND}$ |
| | Feb 2019 | $15.1\pm0.2_{A}^{x}$ | $1101\pm44.5_{AB}^{x}$ | $370\pm0.188_{ABC}^{x}$ | $314\pm0.52_{A}^{x}$ | $36.0\pm0.7_{A}^{x}$ | 0 |
| | Feb 2020 | $17.8\pm0.4_{A}^{y}$ | $992\pm244_{AB}^{x}$ | $597\pm226_{CDE}^{y}$ | $427\pm80.2_{A}^{xy}$ | $40.4\pm2.1_{A}^{x}$ | 0 |
| | **Mean** | **17.8±2.7** | **1066.4±64.5** | **535.3±144.7** | **414.3±94.6** | **36.9±3.1** | **4.8±0.6** |
| Amazing | Feb 2018 | $19.5\pm1.0_{A}^{b}$ | $902\pm114.1_{AB}^{a}$ | $483.0\pm26.0_{ABCD}^{b}$ | $409.3\pm36.9_{A}^{b}$ | $32.7\pm10.3_{A}^{b}$ | $35.0\pm6.2_{A}^{b}$ |
| | Feb 2019 | $12.3\pm2.8_{A}^{a}$ | $825\pm35.6_{AB}^{a}$ | $262\pm85.6_{AB}^{a}$ | $212.0\pm27.1_{A}^{a}$ | $36.2\pm3.1_{A}^{a}$ | $10.4\pm6.3_{A}^{a}$ |
| | Feb 2020 | $12.8\pm2.0_{A}^{a}$ | $654\pm208.5_{A}^{a}$ | $258\pm113.3_{A}^{a}$ | $204\pm23.5_{A}^{a}$ | $29.6\pm3.6_{A}^{a}$ | $14.5\pm1.8_{A}^{a}$ |
| | **Mean** | **14.9±4.0** | **793.7±126.9** | **334.3±128.8** | **275.0±116.1** | **32.8±3.3** | **20.0±13.2** |

Values represented as mean ± SD

For each column different lowercase letters indicate significantly different at $p \leq 0.05$ as measured by Tukey's test within a variety in different year

For each column different uppercase letters indicate significantly different at $p \leq 0.05$ as measured by Tukey's test between different varieties in different years

### 3.2 Physiological Disorder

Physiological disorders of cauliflower curds are of great importance for the commercial quality of the yield. The occurrence of fuzziness was observed in the greenhouse-grown crop, and it ranged from 0-35±6.2% of the harvested curd depending on the year and variety (Table 3). Fuzziness was not observed in cv Shentha while 10.4-35 % of cv Amazing exhibited fuzziness. Curd defects are related to temperature fluctuations outside of the optimum range for a particular stage of development. Normal curds are formed at 10-25 ºC depending on the variety. Fuzziness occurs above this temperature range and the extent of fuzziness increases as the growing temperature increased[8]. The mean maximum temperature recorded inside the greenhouse was 31.8±4.5ºC in 2017-18; 30±4.9 ºC in 2018-19; 29.6±6.2 ºC in 2019-20, which is much above the optimum temperature range for curd development. However, despite the high temperature the number of curds with fuzziness was relatively small (0, 4.8±0.6, 20.0±13.2% in 2018, 2019, 2020, respectively). It may be because the extend of fuzziness decreased when curds are exposed to high temperatures in the advanced stage of the development[8].

## 4. CONCLUSION

Cauliflower is traditionally not grown during winter months in the trans-Himalayan Ladakh region. Only freeze-tolerant leafy vegetables are grown in the passive solar greenhouse because of sub-zero degree Celsius at night. The feasibility of growing cauliflower, a temperature sensitive crop, was studied during winter months in a passive solar greenhouse. Studies conducted during 2017-2020 showed that cauliflower can be successfully grown during winter months in the trans-Himalaya in winter months under passive solar greenhouse. Harvesting was done in the month of February and the mean marketable curd weight ranged from 258±113 to 743±62 g depending on variety and year. However, the marketable curd weight was significantly lower as compared to the yield potential and occurrence of physiological disorders was observed.

**Conflict of Interest:** None

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