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Growing kohlrabi (*Brassica oleracea* var *gongylodes*) in greenhouse during winter in trans-Himalayan Ladakh, India

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Abstract: Studies were conducted in two winter seasons (2017-2019) to find out the possibility to grow kohlrabi, a temperature sensitive crop, under high diurnal temperature variation in a passive solar greenhouse in Ladakh region (elevation 3340 m). Salable knobs were formed despite the high diurnal temperature variation (27.4±2.6°C) inside the greenhouse. The salable knob weight of the variety White Vienna and Pusa Virat was 190.3±20.3 and 108.8±0.7g, respectively. The occurrence of knob cracking and deformed knobs were observed. Dramatic declines in photosynthetic rate, intercellular CO_2 concentration, and transpiration rate was observed when the plants were exposed to high temperatures. Despite the mean air temperature outside the ideal range of 15-25°C, salable knobs were formed inside the greenhouse during winter. Shading results in vertical elongation of the swollen bulb-like stem. We found that cracking of knobs is genetically determined. The study suggested that kohlrabi can be successfully grown during winter months in the trans-Himalayan Ladakh.

Keywords: *Brassica oleracea*; knol-khol; Ladakh; passive solar greenhouse; protected cultivation; shadings

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1. Introduction

Long harsh winters in high mountain regions, such as Ladakh in the trans-Himalaya, decrease the crop growing season to just 4-5 months in a year. The accessibility to fresh fruits and vegetables decreases significantly during the winter. Low dietary diversity and seasonal shortfall results in micronutrient deficiencies, which is often termed as 'hidden hunger' (Dame and Nüsser, 2011).

Meeting the requirement for fresh fruits and vegetables during winter season at an reasonable price is, therefore, a challenging task in the remote mountain regions (Angmo *et al.* 2017). Low-cost passive solar greenhouse has become popular in such areas for growing vegetables. However, the temperature inside the low-cost greenhouse often falls to below freezing temperature at night during winter, which confines growing of only freeze tolerant leafy vegetables (Angmo *et al.* 2019).

Kohlrabi is a cool-season temperature sensitive crop grown for its swollen bulb-like stem called knob. The optimum temperature for its growth is 15-25ºC (Dhaliwal, 2017). Knob development is sensitive to temperature extremes. If temperatures fall below 15ºC for a longer period, early maturing varieties develop flowering stalks without forming the knobs. At higher temperature, the knobs become fiberous and taste bitter (Dhaliwal, 2017). Temperature higher than 20°C promote intensive leaf growth (Lešić *et al.* 2004). Growing of kohlrabi during freezing winter in traditional passive solar greenhouse in high altitude Ladakh region results in plants with stunted growth, curly leaves, cracking of knob and formation of ice crystal due to cold stress (Spaldon *et al.* 2018). This study was, therefore, conducted to determine possibility of growing kohlrabi during winter in an improvised passive solar greenhouse. The study also aimed to determine the effects of high diurnal temperature variation and red shade net on growth and photosynthesis during freezing winter.

2. Materials and Methods

2.1. *Study Site and Growing Conditions*

Experiments were conducted in two winter seasons (2017-2019). Kohlrabi was grown in an improvised passive solar greenhouse (IP Greenhouse) and Polynet greenhouse in Leh Ladakh, India (34°08.2′N; 77°34.3′E, elevation 3340 m). Both IP and Polynet greenhouse are passive solar greenhouse of same size (length 90 feet; width 27 feet; height 9 feet) in east-west orientation having stone wall on three sides. Both have a sloped wooden roof on the north side of the greenhouse. IP Greenhouse is covered with a clear 16-mm triple layer UV-stabilized polycarbonate panel on the south-facing side, while Polynet is covered with a layer of red shade net (60%) and 120 GSM UV stabilized translucent polyethylene sheet (Angmo *et al.*, 2019). No supplementary lighting and heating were provided in both the greenhouse. The structures were not covered with any thermal blanket, even in the peak winter. Temperature and relative humidity were recorded daily with a hygro-thermometer (445702, Extech Instruments). Photosynthetically active radiation (PAR) was recorded with a radiometer (PMA2100, Solar Light) with a PAR detector (PMA2132). The weather data of the two greenhouses are shown in Table 1.

2.2. Experimental Design

The studies were conducted with two varieties - White Vienna and Pusa Virat. Randomized block experimental design was used with three replications. Each replication plot was 2.8 × 1.7 m with 48 plants each spaced at 20×20 cm. FYM (3.4 kg per m^2) was applied at the time of field preparation. Chemical fertilizer, pesticide and weedicides were not used all throughout its growing cycye. Seedlings with 2-4 leaves were transplanted on 16 Oct 2017 and 01 Oct 2018. Weeding was done twice during the growing season.

2.3. Growth and Yield Attributes

Data was 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. RGR, SLA, LWR and NAR were determined as described by (Hunt *et al.* 2002). Knob weight at fresh market maturity was recorded two times in a season. All knobs were trimmed to market standards and weighed. At harvest, the plants were assessed for knob quality defects. The number of crack and deformed knobs were counted and expressed as a percentage of the total knobs harvested per plot. Photosynthetic parameters were studied on clear sky day in mid-December using a Portable Photosynthesis System (CIRAS-3, PP Systems, USA). The data was recorded on a fully expanded leaf. Five replicates per treatment were recorded.

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. Microclimate inside the greenhouses

The microclimate inside the two greenhouses is shown in Table 1. The mean monthly maximum temperature inside the IP greenhouse ranged from

26.8±8.3 to 38.8±2.7ºC, while the minimum temperature ranged from 1.2±0.8 to 10.4±0.9ºC. The mean diurnal temperature variation was 27.4±2.6ºC. The Polynet greenhouse was 4.3ºC cooler during day time and 3.5ºC colder at night as compared to the IP Greenhouse. The diurnal temperature variation inside Polynet greenhouse was 26.6±2.9ºC. The difference in temperature inside the two greenhouses was due to use of different covering materials. Polycarbonate has better thermal efficiency as compared to polyethylene. The mean maximum and minimum relative humidity inside the IP greenhouse was 92.7±4.5 and 44.3±19.1% as against 94.6±1.1 and 52.1±10.1%, respectively in Polynet greenhouse. A significant difference in PAR was observed between the two greenhouses. At noon the mean PAR inside IP greenhouse was 579.0±172.8 μmol/m^{2}s as against 278.6±62.1 μmol/m^{2}s inside the Polynet greenhouse. Higher relative humidity and lower PAR inside the Polynet greenhouse are may be due to the red shade net.

3.2. Growth Attributes

The growth of kohlrabi plants was determined by their RGR. The RGR was higher in the crop grown under IP greenhouse in both the varieties (Table 2). Lower RGR inside the Polynet greenhouse may be due to low PAR and colder night temperature. In the sub-optimal temperature range, the RGR reduce at lower average temperatures (Venema *et al.* 1999). Low PAR inside the Polynet greenhouse also caused a decrease in the ratio of leaf area to leaf dry mass (an increase of SLA). By increasing the SLA, the plant presumably increases its potential of light interception per unit of structural biomass invested in the leaves. Similar results have been reported in cabbage and lettuce (Wolff and Coltman, 1990). This strategy has been recognized as an economic strategy to maintain sufficient productivity. In our studies, the higher SLA observed under the Polynet greenhouse tended to be related to low leaf dry matter content allocated to the leaves associated with a smaller number of leaves, and thus larger and thinner individual leaves. The NAR, which refers to the net efficiency of plant photosynthesis, was significantly higher in IP greenhouse. The mean NAR in White Vienna and Pusa Virat inside IP greenhouse was 1.13±0.22 and 0.78±0.21 mg cm^{-2} d^{-1} as against 0.88±0.21 and 0.53±0.13 mg cm^{-2} d^{-1}, respectively inside Polynet greenhouse. Under shaded conditions of Polynet greenhouse, plants had thinner leaves and thinner stems, which is in agreement with the previous report by (Díaz-Pérez, 2013). Plants undergo morphological changes under low light to maximize light use. Plants adapted to shade have higher foliar surface and specific leaf area, thinner leaves, and taller stems compared with plants adapted to strong light (Larcher, 1995).

The optimum temperature range for kohlrabi growth and formation of proper thickened stem is 15-20°C during the day and 8-12°C at night (Benko, 2017). Knob development is sensitive to temperature extremes. If temperatures fall below 15ºC for a longer period, early maturing varieties develop flowering stalks without forming the knobs. Temperature higher than 20°C promote intensive leaf growth (Lešić *et al.* 2004). At higher temperatures, the knobs become fiberous and taste bitter (Dhaliwal, 2017). The mean minimum and maximum temperature recorded inside the IP greenhouse was 32.4±5.0 and 5.0±4.0ºC, respectively, during the growing period. The crop survived occasional sub zero degree Celsius at night. Despite the average air temperature beyond the ideal range of 15-25ºC, marketable knobs were formed inside IP greenhouse (Figure 1). However, marketable knobs were not formed inside the Polynet greenhouse in both the varieties, which may be due to lower night temperature and PAR inside the greenhouse.

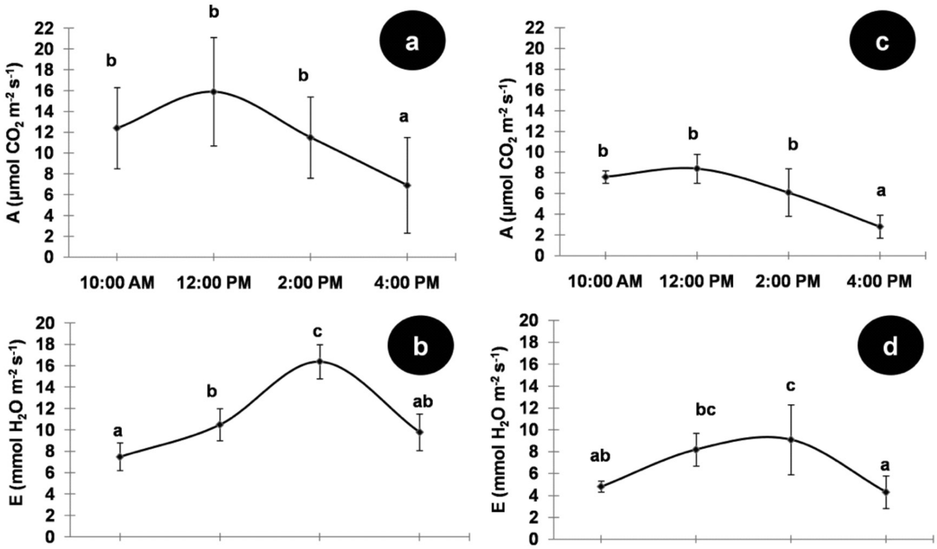
3.3. *Photosynthesis and Transpiration*

Photosynthesis was measured to assess the effect of temperature and light stress on greenhouse kohlrabi. The change in intercellular CO_2 concentration (Ci), photosynthetic rate (A), and transpiration rate (E) measured at different time intervals are shown in Figure 2. Ci, which essentially indicates the CO_2 substrate available for photosynthetic assimilation, was maximum at 10 AM in both the greenhouses. Lowest Ci was observed at 2:00 PM inside IP greenhouse, which may be due to high temperature (30ºC) and vapour pressure difference (VPD) of 0.7 kPa. However, despite the highest temperature (25.4ºC) and VPD (0.36 kPa) at 2:00 PM, the lowest Ci was observed at 12 noon inside the Polynet greenhouse. High temperature inside the greenhouse resulted in high E at 2:00 PM. A sharp increase in E above 25ºC has also been reported in Chinese cabbage (Oh *et al.* 2015). Despite the high Ci coupled with low VPD at 10:00 AM, the highest photosynthetic rate was observed at 12 noon in both IP greenhouse (15.9±5.2 µmol CO_2 m^{-2} s^{-1}) and Polynet greenhouse (8.4±1.4 µmol CO_2 m^{-2} s^{-1}) which could be due to optimal temperature at noon (26ºC inside IP greenhouse; 24.5ºC inside Polynet greenhouse). The photosynthetic rate was found 1.6 to 2.5-fold higher in crops under the IP greenhouse, which could be due to higher PAR inside the greenhouse. The result is in agreement with Díaz-Pérez (2013), who reported that net photosynthesis decreased with increased shade level, particularly above 47% shade level.

3.4. Marketable yield

Harvesting was carried out on 10-16 January in 2018 and 1-18 January in 2019. The mean marketable knob weight of the variety White Vienna and Pusa Virat was 190.3±20.3 and 108.8±0.7 g, respectively, during the two year study period in IP greenhouse (Table 3). The marketable knob weight was significantly lower as compared to the yield potential of the varieties. The yield potential of variety Pusa Virat is 800-900 g. Besides, it took more number of days to harvest as compared to the expected days to harvest for each variety. White Vienna is an early maturing variety and takes 55-60 days to reach marketable maturity (Dhaliwal, 2017). In contrast, it took 93 days to harvest from the date of transplanting. Low knob weight and longer days to harvest in the present study may be due to high diurnal temperature variation inside the greenhouse. It has been observed that cabbage grown at 25°C has a lower dry matter content, reduced growth rate and lower water use efficiency than cabbage grown at 20°C (Hara and Sonoda, 1982). Warland *et al.* 2006 reported that the yield decrease by 10% for every 10 days that the temperature exceeds 30°C. Higher yield and head quality are expected if excessive heat that builds up inside the greenhouse is controlled through ventilation.

Figure 1: Marketable knobs of (a) White Vienna and (b) Pusa Virat formed inside the greenhouse.



Time	: 10:00 AM	12:00 PM	2:00 PM	4:00 PM	10:00 AM	12:00 PM	2:00 PM	4:00 PM
Ci (µmol mol⁻¹) :	464	342	325	349	439	365	381	412
Temp (°C) :	14.5	24.5	30.0	23.8	12.6	26.0	26.9	16.4
VPD (kPa) :	0.26	0.55	0.70	0.31	0.19	0.27	0.36	0.22
PAR (µmol/m²s) :	304	701	423	182	153	249	221	78

Figure 2: Relationship between intercellular CO_2 concentration (Ci); temperature; vapour pressure difference (VPD) and photosynthetically active radiation (PAR) with (a) photosynthesis rate (A) under IP greenhouse; (b) transpiration rate (E) under IP greenhouse; (c) photosynthesis rate (A) under Polynet greenhouse; (d) transpiration rate (E) under Polynet greenhouse in kohlrabi (White Vienna) leaves in mid-December.

3.5. Physiological Disorder

The occurrence of physiological disorders were observed. Cracking was observed in 1.5±2.1% of the knobs in White Vienna and 15.6±4.2% of Pusa Virat. It is commonly believed that cracking occurs as a result of non-optimal soil moisture (Benko, 2017). However, in the present study, it was found that cracking of knobs is genetically determined. A high percentage of the harvested crops were having deformed knobs in both the varieties (White Vienna: 19.8±20.2%; Pusa Virat: 24.8±15.9%), which may be due to low night temperature. Varietal characteristics of White Vienna is globular-round knob and that of Pusa Virat is round knob (Dhaliwal, 2017). The knob shape in terms of sphericity was 89.5±3.3% in White Vienna and 90.5±1.1% in Pusa Virat when grown under IP greenhouse. However, under the shade condition of Polynet greenhouse the sphericity of White Vienna and Pusa Virat reduced to 61.7±3.5% and 66.7±6.1%, respectively. Therefore, the use of Polynet shade resulted in vertical elongation of the swollen bulb-like stem.

Table 1: Microclimate inside two passive solar greenhouse during winter season in trans-Himalayan Ladakh region

Greenhouse	*Period*	*Month*	*Temperature in open field (ºC)*		*Temperature inside greenhouse (ºC)*			*Relative humidity inside greenhouse (%)*		*PAR at 12 noon inside greenhouse (µmol/m²s)*
			Max	*Min*	*Max*	*Min*	*Max-Min*	*Max*	*Min*	
Improvised Polycarbonate (IP)	2017-18 (16 Oct 2017 to 16 Jan 2018)	Oct	11.6±1.8	-4.6±0.5	38.8±2.7	10.4±0.9	28.4±1.8	87.4±3.5	22.1±4.0	833.2±83.5
		Nov	7.9±3.8	-7.7±2.9	33.0±6.2	5.3±2.5	27.7±3.7	90.5±5.7	34.8±17.3	458.6±268.4
		Dec	3.6±1.8	-10.8±2.4	26.8±8.3	3.1±1.1	23.7±7.2	96.5±2.5	62.5±15.9	484.3±239.1
		Jan	1.2±2.4	-14.4±3.0	30.9±2.4	1.2±0.8	29.7±1.6	96.3±2.0	57.9±7.2	540.0±69.5
		Mean	6.1±4.6	-9.4±4.2	32.4±5.0	5.0±4.0	27.4±2.6	92.7±4.5	44.3±19.1	579.0±172.8
Polynet	2017-18 (16 Oct 2017 to 16 Jan 2018)	Oct	11.6±1.8	-4.6±0.5	34.2±2.0	7.4±1.0	26.8±1.0	93.8±3.4	40.2±4.1	355.1±49.7
		Nov	7.9±3.8	-7.7±2.9	28.3±4.6	2.5±2.3	25.8±2.3	95.1±2.0	49.5±11.7	232.3±140.1
		Dec	3.6±1.8	-10.8±2.4	23.0±7.1	-0.4±1.6	23.4±5.5	95.9±0.8	64.5±12.4	224.0±110.6
		Jan	1.2±2.4	-14.4±3.0	26.7±2.0	-3.7±1.3	30.4±0.7	93.6±1.1	54.3±8.4	302.9±32.0
		Mean	6.1±4.6	-9.4±4.2	28.1±4.7	1.5±4.7	26.6±2.9	94.6±1.1	52.1±10.1	278.6±62.1

Values represented as mean ± SD

Table 2: Growth parameters of two commercial varieties of kohlrabi in 2017-18 winter seasons under two passive solar greenhouses

Growth parameters	*DAT*	*IP Greenhouse*		*Polynet Greenhouse*	
		White Vienna	*Pusa Virat*	*White Vienna*	*Pusa Virat*
Plant height (cm)	30	$27.3\pm3.0_{A}^{ab}$	$24.4\pm1.8_{A}^{a}$	$31.4\pm2.0_{A}^{b}$	$28.8\pm3.3_{A}^{b}$
	60	$42.0\pm4.6_{B}^{ab}$	$35.2\pm2.8_{B}^{a}$	$43.7\pm5.6_{B}^{b}$	$39.0\pm5.0_{B}^{ab}$
	87	$44.0\pm1.3_{B}^{b}$	$37.6\pm3.6_{B}^{a}$	$44.2\pm4.2_{B}^{b}$	$39.4\pm5.1_{B}^{ab}$
No. of leaves	30	$8.2\pm0.8_{X}^{b}$	$6.7\pm1.2_{X}^{a}$	$5.7\pm0.5_{X}^{a}$	$6.0\pm0.9_{X}^{a}$
	60	$11.5\pm1.5_{Y}^{b}$	$9.3\pm1.0_{Y}^{a}$	$8.7\pm1.0_{Y}^{a}$	$8.7\pm1.2_{Y}^{a}$
	87	$12.8\pm0.8_{Y}^{b}$	$12.0\pm1.4_{Z}^{ab}$	$10.3\pm1.2_{Z}^{a}$	$11.0\pm1.4_{Z}^{ab}$
Leaf thickness (mm)	30	$0.30\pm0.06_{AB}^{bc}$	$0.34\pm0.04_{AB}^{c}$	$0.21\pm0.03_{AB}^{a}$	$0.24\pm0.04_{A}^{ab}$
	60	$0.34\pm0.02_{B}^{bc}$	$0.37\pm0.05_{B}^{c}$	$0.24\pm0.04_{B}^{a}$	$0.30\pm0.03_{B}^{b}$
	87	$0.26\pm0.05_{A}^{b}$	$0.29\pm0.04_{A}^{b}$	$0.17\pm0.02_{A}^{a}$	$0.24\pm0.03_{A}^{b}$
Chlorophyll content (SPAD)	30	$45.8\pm2.8_{X}^{a}$	$47.2\pm1.9_{X}^{a}$	$46.8\pm5.9_{X}^{a}$	$45.5\pm14.8_{X}^{a}$
	60	$50.4\pm6.0_{X}^{a}$	$45.5\pm3.5_{X}^{a}$	$51.1\pm4.5_{X}^{a}$	$49.2\pm3.1_{X}^{a}$
	87	$44.3\pm6.5_{X}^{a}$	$47.5\pm3.3_{X}^{a}$	$52.1\pm5.6_{X}^{a}$	$48.4\pm7.8_{X}^{a}$
Stem length (cm)	30	$3.4\pm0.5_{A}^{b}$	$2.3\pm0.3_{A}^{a}$	$8.7\pm0.7_{A}^{d}$	$5.6\pm0.5_{A}^{c}$
	60	$3.5\pm0.5_{A}^{ab}$	$2.4\pm0.5_{AB}^{a}$	$8.9\pm0.7_{A}^{c}$	$5.8\pm0.7_{A}^{bc}$
	87	$3.6\pm0.7_{A}^{a}$	$3.1\pm0.6_{B}^{a}$	$9.3\pm2.6_{A}^{c}$	$6.4\pm0.8_{A}^{b}$
Stem diameter (mm)	30	$10.0\pm1.5_{X}^{b}$	$9.6\pm1.0_{X}^{b}$	$7.6\pm1.3_{X}^{a}$	$6.2\pm0.8_{X}^{a}$
	60	$10.9\pm1.0_{X}^{a}$	$12.4\pm0.7_{Y}^{b}$	$10.0\pm0.6_{Y}^{a}$	$9.7\pm2.2_{Y}^{a}$
	87	$11.9\pm1.3_{X}^{ab}$	$13.0\pm2.4_{Y}^{b}$	$11.0\pm0.9_{Y}^{ab}$	$10.1\pm1.9_{Y}^{a}$
LA	90	1733.7 ± 309.5^{bc}	1834.1 ± 459.1^{c}	834.3 ± 106.4^{a}	1118.7 ± 221^{ab}
RGR	0-90	58.5 ± 5.7^{b}	53.5 ± 3.6^{ab}	49.0 ± 4.2^{a}	45.7 ± 3.9^{a}
SLA	0-90	97.4 ± 5.0^{a}	100.2 ± 18.4^{ab}	108.4 ± 6.6^{ab}	137.6 ± 32.4^{b}
LWR	0-90	0.53 ± 0.08^{a}	0.73 ± 0.26^{a}	0.53 ± 0.05^{a}	0.63 ± 0.10^{a}
LAR	0-90	51.4 ± 6.2^{a}	71.5 ± 19.4^{ab}	56.8 ± 8.1^{a}	85.4 ± 13.3^{b}
NAR	0-90	1.13 ± 0.22^{b}	0.78 ± 0.21^{ab}	0.88 ± 0.21^{ab}	0.53 ± 0.13^{a}

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 different variety at a given time period

For each column, different uppercase letters indicate significantly different at $p \leq 0.05$, as measured by Tukey's test within a variety at different DAT

LA: leaf area (cm^2); RGR: relative growth rate ($mg\ g^{-1}\ d^{-1}$); SLA: specific leaf area ($cm^2 g^{-1}$); LWR: leaf weight ratio (g / g^{-1}); LAR: leaf area ratio ($cm^{-2}\ g^{-1}$); NAR: net assimilation rate ($mg\ cm^{-2}\ d^{-1}$)

Table 3: Kohlrabi yield and physiological disorders under two passive solar greenhouses in winter seasons in trans-Himalayan Ladakh

Variety	*Greenhouse*	*Year*	*Yield parameters*			*Physiological disorder (%)*	
			Knob weight (g)	*Gross weight (g)*	*Harvest index (%)*	*Cracking*	*Deformed*
White Vienna	Polynet	2018	$33.0\pm1.8_{A}^{a}$	$85.0\pm8.3_{A}^{a}$	$24.4\pm5.6_{A}^{a}$	$0.0\pm0.0_{A}^{a}$	$100.0\pm0.0_{C}^{c}$
	IP Green-house	2018	$175.9\pm18.5_{BC}^{b}$	$245.0\pm29.1_{B}^{b}$	$63.2\pm9.3_{C}^{b}$	$3.0\pm1.0_{AB}^{b}$	$5.5\pm1.5_{A}^{a}$
	IP Green-house	2019	$204.6\pm47.9_{C}^{b}$	$250.6\pm58.3_{B}^{b}$	$70.7\pm1.8_{C}^{b}$	$0.0\pm0.0_{A}^{a}$	$34.0\pm11.1_{B}^{b}$
Pusa Virat	Polynet	2018	$27.1\pm6.4_{A}^{a}$	$92.2\pm14.7_{A}^{a}$	$26.2\pm8.6_{A}^{a}$	$7.3\pm1.5_{ABC}^{a}$	$100.0\pm0.0_{C}^{c}$
	IP Green-house	2018	$109.3\pm18.6_{B}^{b}$	$205.7\pm27.1_{B}^{b}$	$44.3\pm1.5_{B}^{b}$	$18.5\pm1.5_{C}^{b}$	$13.5\pm1.5_{A}^{a}$
	IP Green-house	2019	$108.3\pm33.6_{B}^{b}$	$151.3\pm63.9_{AB}^{b}$	$58.5\pm6.8_{BC}^{b}$	$12.6\pm10.5_{BC}^{a}$	$36.0\pm9.0_{B}^{b}$

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

4. Conclusion

The study suggested that kohlrabi can be successfully grown during winter months in the trans-Himalayan Ladakh. Despite the air temperature beyond the ideal range of 15-25ºC, salable knobs were formed inside the greenhouse with high diurnal temperature variation of 27.4±2.6ºC. Shading results in vertical elongation of the swollen bulb-like stem.

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