

## International Journal of Agriculture Extension and Social Development

Volume 7; SP-Issue 2; Feb 2024; Page No. 54-58

Received: 26-12-2023  
Accepted: 30-01-2023

Indexed Journal  
Peer Reviewed Journal

### Exploring the potential of tomatoes in Ladakh's cold arid landscape through passive solar greenhouse cultivation

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DOI: <https://doi.org/10.33545/26180723.2024.v7.i2Sa.333>

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#### Abstract

Ladakh is identified as one of the coldest, driest and highest regions in the world. Temperature regime of the region is the major limiting factor in agriculture where only cold hardy crops are cultivated during summer and this restricts agricultural season to few months. Spiritual inclination of the predominant Buddhist community embracing vegetarian diet makes vegetable cultivation essential for meeting nutritional security of the region. Open conditions allow cultivation of only cool season crops. Therefore, under Ladakh conditions, protected vegetable cultivation is indispensable for both food and nutritional security and for year round harvest. Warm season crops like tomatoes perform best to their potential when they are cultivated under protected conditions during summer months. To evaluate different tomato varieties under greenhouse conditions, a study was taken up in kharif 2023-2024 at KVK Leh in Ladakh. Five potential hybrids were selected for the study. Among the hybrids, Arka Samrat recorded highest plant height (137 cm) followed by PH-2 (124.667) and Uphar (122.33) which are significantly at par with each other. The least plant height was recorded in Anand (91.33 cm) which is significantly at par with US-1080 (98.5). Highest root length was recorded in Uphar (26.63 cm) followed by Arka Samrat (20.2 cm) which is statistically at par with PH-2 (19.2 cm). NBH-Anand (Improved) recorded highest fruit Polar diameter (6.1 cm) while PH-2 recorded highest equatorial diameter (5.53 cm). TSS percentage was recorded maximum in Arka Samrat (7%) and is statistically at par with PH-2 (6.77%). The minimum Total soluble solid content was recorded in US-1080 (5.7%). Highest yield per plant and per hectare was recorded in hybrid PH-2 (1457.7 g, 53.99t/ha) which is significantly at par with Hybrid Uphar (1376.7 g, 50.99t/ha). The least yield per plant and per hectare was recorded in Arka Samrat (835.3 g, 30.94 t/ha). Tomato hybrids PH-2 followed by Uphar are best in terms of yield and taste and are therefore recommended for cultivation under greenhouse conditions in Ladakh.

**Keywords:** Greenhouse, hybrids, Ladakh, nutritional security, vegetarian diet, yield and taste

#### Introduction

Tomato (*Solanum lycopersicum* L.) is one of the most popular and widely grown vegetables in the world with an annual value exceeding 90 billion USD (FAOSTAT 2019) [7]. India is the second-largest producer of tomato after China. According to FAOSTAT 2018 [6], India produced 18.74 million tons with productivity rate 21.24 ton/Ha. It stands as one of the most versatile and widely consumed fruits globally ranking second in importance only next to potato and ranked first in preserved and processed vegetables and in the international market there is great demand for tomato. The nutritional profile of tomatoes adds to their allure as it's a rich source of antioxidants especially carotenoids. Among the common dietary carotenoids lycopene has the highest singlet oxygen quenching capacity *in vitro* (Gersten, 1997) [8].

As Ladakh is identified as one of the coldest, driest and highest regions in the world, open conditions allow cultivation of only cool season crops from May to Sep-Oct as temperature in Spring, Autumn and Winter dips below zero restricting crop production beyond this period (Figure 1). Therefore, under Ladakh conditions, protected vegetable cultivation is indispensable for both food and nutritional security and for year round harvest (Lamo *et al.*, 2020) [15].

Warm season crops like tomatoes perform best to their potential when they are cultivated under protected conditions during summer months. The daily mean temperature inside greenhouses in Ladakh remains above zero degrees and therefore cultivation during harsh periods becomes possible (Figure 2). Tomato crop grows quite well under open conditions in most northern regions of India but the crop fails to mature to its highest potential under the high altitude cold arid conditions of Ladakh (especially in the mid and upper belts). In such conditions, growing tomato under protected conditions becomes essential for maximum marketable yield (Fig. 4).

Tomato crop has wider adaptability, high yielding potential and multipurpose uses in fresh as well as processed food industries (Dar *et al.*, 2015) [5]. Development of tomato genotypes of a promising nature has been important to the vegetable industry throughout the world. Currently, tomato is the pivotal point of horticultural industry and is growing worldwide either for fresh market or processing. Tomato varietal evaluation for production traits is a cornerstone in modern agriculture. It's the gateway to optimizing yields, ensuring resilience against diseases, and tailoring varieties to diverse environments. Evaluation not only enhances crop productivity but also minimizes resource usage and fosters

genetic diversity, contributing significantly to sustainable agricultural practices and ensuring a consistent supply of high-quality tomatoes that meet consumer preferences. By understanding and refining the process of varietal evaluation, we aim to contribute to the adoption of superior tomato cultivars for growing under protected conditions in Ladakh that not only meet today's changing markets

demands catering to different sectors like army, locals, tourism and floating population but also contribute to sustainable and resilient agricultural systems. This paper aims to explore the implications of varietal evaluation under protected conditions in enhancing tomato crop performance and quality under Cold arid conditions of Ladakh.

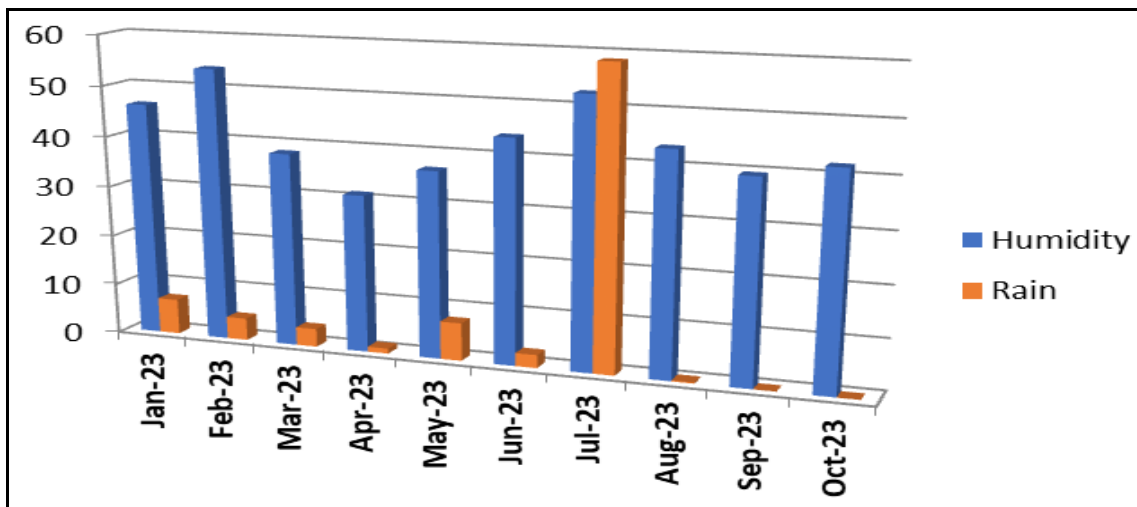
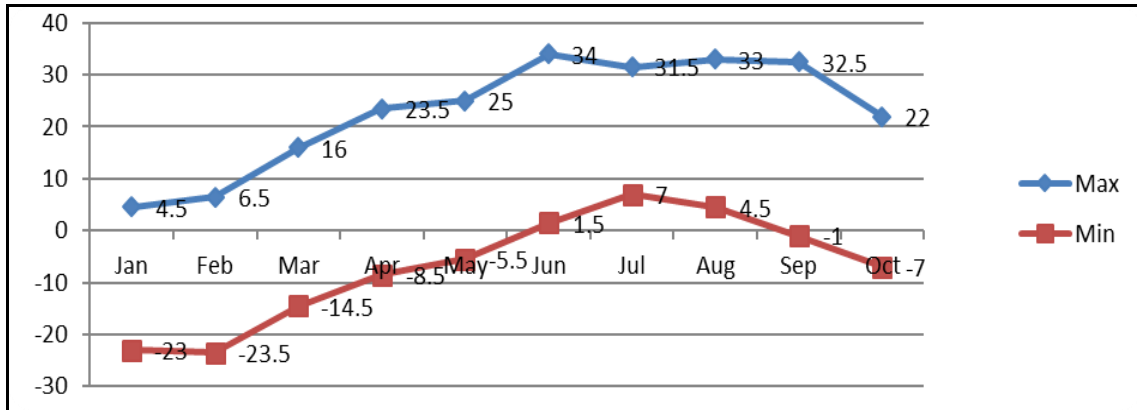


Fig 1: Leh Agormetero data under open conditions from Jan to Oct 2023 (source AMFU-Leh)

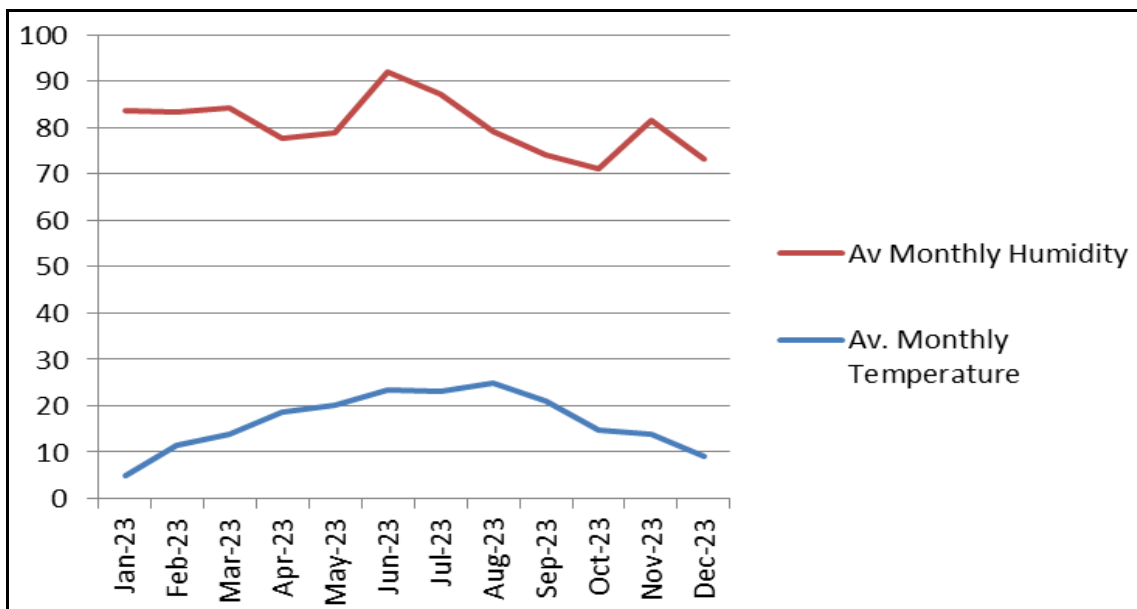


Fig 2: Temperature and Humidity data inside Chinese greenhouse from Jan to Dec 2023 (Source: Digi logger)

## Materials and Methods

The experiment was conducted at Krishi Vigyan Kendra-Leh, SKUAST-K located at 3305 m amsl with latitude 33.975383 and longitude 77.699674 under protected conditions from May to September 2023 to study the performance of five hybrids *viz.*, US-1080, Uphar, PH-2, Arka Samrat and Anand. Experimental design was RCBD with Five hybrids replicated thrice. The climate of the area is typically dry temperate. The protected structure used was a Chinese type greenhouse with a dimension of 100x32 sqft. There were 15 plots each containing 12 number of tomato plants with a spacing of 60 cm x 45 cm for rows and plants. Transplanting of 35 days old seedling was done in the month of May, 2023. NPK dose was applied at the rate of 120:60:60 kg per ha and 15 ton FYM.  $\frac{1}{2}$  N and full dose of

FYM, DAP and MOP were used as basal dose.  $\frac{1}{2}$  N was applied 30 days after transplanting. All the recommended cultural practices were adopted for raising the crop successfully. The observations were recorded on five randomly selected plants per replication for each genotype on eight characters: i) Plant height (cm), ii) Root length (g), iii) Polar diameter (cm), iv) Equatorial diameter (cm), v) Fruit yield per plant (g), vi) Fruit yield per hectare, vii) average fruit weight and viii) total soluble solids (%). Multiple manual harvesting of fruit was done at 4-5 days interval. Mean across three replications were calculated for each trait and the mean performance is assessed. The recorded data were statistically analyzed at 5% level of significance following the standard process using CPCS-1 data analysis package.



Fig 3: Tomato harvest in August under Chinese Greenhouse at KVK-Leh (3305 m amsl)

## Results and Discussion

The results obtained from the present field experiment during Kharif season of the year 2023-24 on plant height (cm), Root length (g), polar diameter (cm), equatorial diameter (cm), fruit yield per plant (g), Fruit yield per hectare and (h) total soluble solids (%) exhibited significant differences (Fig.4)

### Plant Height (cm)

Perusal of the data presented in Table1 revealed that among all the five Tomato hybrids, Arka Samrat recorded highest plant height (137 cm) followed by PH-2 (124.667) and Uphar (122.33) which are significantly at par with each other. The least plant height was recorded in Anand (91.33 cm) which is significantly at par with US-1080 (98.5). Plant height is a good index of plant vigour that may contribute in higher yields. Morphological differences are varietal characteristics and which are controlled and expressed by certain genes. Accordingly, the presence of variation in plant height is the result of inherent genetic capacity of hybrids. It confirms to the findings of Hazarika and Phookan [2005] [12]. Haque *et al.* (1988) [11] also reported that line TMO 369 produced the tallest plant (116.60 cm) and line TMO 260 gave the shortest plants of 47.63 cm height during evaluation of tomato lines. Kallo *et al.* (1998) [14] also reported differences in plant height among cultivars/hybrids of tomato put under evaluation and screening trials.

### Root Length (cm)

Root systems perform the crucial task of providing water,

nutrients and physical support to the plant. The length of the main root and the density of the lateral roots determine the architecture of the root system in tomato and other dicots and play a major role in determining whether a plant will succeed in a particular environment. It is evident from the table (1) that root lengths recorded significant differences among the Hybrids. Highest root length was recorded in Uphar (26.63 cm) followed by Arka Samrat (20.2 cm) which is statistically at par with PH-2 (19.2 cm). The least root length was recorded in Anand (11.23 cm). It is evident from the data that the variety/hybrid with deepest roots are better yielders than those with shorter ones. This may be due to better access to nutrients and better stand in the field.

### Fruit Polar Diameter (cm) and Equatorial diameter (cm)

Data revealed that NBH-Anand (Improved) recorded highest Polar diameter (6.1 cm) which is followed by Arka Samrat (5.767). The least polar diameter was recorded in US-1080. Higher polar diameter in Anand conforms to its varietal trait with oval fruit shape. Significant differences were also recorded among the hybrids for fruit equatorial diameter. PH-2 recorded highest fruit equatorial diameter (5.53 cm) which is significantly at par with Arka Samrat. Both the hybrids display rounded fruit shape. Anand recorded least fruit equatorial diameter (4.2 cm) which is significantly at par with US-1080 and Uphar. The variation in fruit size in different tomato hybrids is reported to be inter varietal associated with the genetic makeup of cultivars and governed by the cell size and intercellular space of the flesh. Earlier studies also have the similar findings for fruit size [Shaw *et al.* 2002 and Golani *et al.* 2007] [18, 9].

**TSS (%)**

Total soluble solid (TSS) is very important quality character and degree of sweetness is determined by TSS. Total soluble solids varied among the five hybrids grown in greenhouse. Perusal of the data revealed that the TSS percentage was maximum in Arka Samrat (7%) and is statistically at par with PH-2 (6.77%). The minimum Total soluble solid content was recorded in US-1080 (5.7%). [Tigist *et al.* 2003 and Beckles *et al.* 2012] <sup>[21, 1]</sup> reported that TSS content is variety dependent and mostly correlates negatively with tomato yield. An agreement to this result, Jindal *et al.* (2015) stated that, the mean performance of three years of tomato TSS was recorded in the variety HS-18 (4.72 ° Brix) which was maximum TSS followed by Dev and TAI-687 (3.99°Brix). Similar results were also reported by Zhu-wei Min *et al.* (2003) <sup>[22]</sup> that indicate tomato cultivar ‘Puhong 909’ had maximum TSS content (4.5%) under the multispan greenhouse. Singh (2011) <sup>[19]</sup> also reported that, the maximum TSS was present in ‘Naveen’ (5.60%) under naturally ventilated polyhouse. The value of total soluble solids content varied from 4.79% to 6.02% in different variety (Hossain *et al.*, 2010) <sup>[13]</sup>. In line with this report, Dar *et al.* (2012) <sup>[4]</sup>; Gupta *et al.* (2011) <sup>[10]</sup> also reported that, quality attributes like total soluble solids of the fruit ranged from 3.67 to 6.0 ° Brix in different tomato varieties. Higher TSS percentage values under Ladakh conditions may be attributed to the region’s intense solar radiation exposure.

**Yield /plant (g)**

The data presented in Table 1 regarding yield per plant

indicate significant differences among the 5 tomato hybrids. It was found that hybrid PH-2 gave highest yield per plant (1457.7 g) which is significantly at par with Hybrid Uphar (1376.7 g). The least yield per plant was recorded in Arka Samrat (835.3 g) which is significantly at par with US-1080 (845.7 g). The low yield of Arka Samrat under protected conditions contradicts the actual yield potential under open conditions. This may be because the hybrid may not have been bred for greenhouse cultivation. The fruit weight per plant in this study agrees with previous reports by Regassa *et al.* (2012) <sup>[20]</sup>, who reported fruit weight per plant ranging between 1.1 and 1.7 kg. The result is also in line with the findings of Saleem *et al.* (2013) <sup>[17]</sup>, who found highest fruit yield per plant (2.48 kg) evaluating 30 tomato genotypes in Pakistan. Similarly, Chernet *et al.* (2013) <sup>[3]</sup> reported the highest fruit yield per plant (2.10 kg) comparing 36 tomato genotypes.

**Yield (t ha<sup>-1</sup>)**

It is evident from Table 1 that significant differences exist among the 5 tomato hybrids for yield per hectare. Maximum yield was recorded in Hybrid PH-2 (53.99t/ha) followed by Uphar. Least yield per hectare was recorded in Hybrid Arka Samrat (30.94 t/ha) which is statistically not less than US-1080 (31.7 t/ha). Since total yield is an attribute of yield per plant, therefore total yield is more in Hybrid PH-2 and least in Arka Samrat. the results coincide with findings of Chapagain *et al.*, (2011) <sup>[2]</sup> fruit yield of tomato might be vary due to the varietal diversity as well as growing condition. They reported significant variation on fruit yield from different varieties of tomato.



**Fig 4:** Different tomato hybrids and their performance under Chinese Greenhouse at KVK-Leh (3305 m amsl)

**Table 1:** Mean growth, yield and quality attributes of tomato hybrids

Varieties	Plant Height (cm)	Root length (cm)	Fruit Polar Diameter (cm)	Fruit Equatorial diameter (cm)	TSS (%)	Yield /plant (g)	Yield (t ha <sup>-1</sup> )	Shape
US-1080	98.50	13.26	4.80	4.40	5.76	854.66	31.66	Square round
Uphar	122.33	23.63	5.66	4.40	6.10	1,376.66	50.99	oval
PH-2	124.66	19.20	5.10	5.53	6.76	1,457.66	53.99	Round
Arka Samrat	137.00	20.20	5.76	5.03	7.00	835.33	30.94	Round
Anand (Improved)	91.33	11.23	6.10	4.20	6.20	1,100.00	40.74	Oval
C.D (5%)	12.31	1.41	0.30	0.70	0.41	101.14	3.74	

**Conclusions**

Results of the present study on evaluation carried out under protected conditions in Ladakh indicated that different tomato hybrids behaved significantly different from each other concerning different parameters. Hybrids PH-2 and Uphar performed best under protected conditions and are therefore recommended for cultivation in Leh-Ladakh during summer months inside greenhouses.

**Acknowledgement**

The authors are highly thankful to KVK-Leh for providing opportunity and facilities to work in this terrain. The authors are grateful to the staff that supported in carrying out this research.

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