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Zero Energy Overwinter Storage of Apple Nursery Plants in trans-Himalayan Ladakh, India

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ABSTRACT

Studies were conducted during 2015 and 2016 to assess the effects of storage conditions on survival of nursery plants in trans-Himalayan Ladakh region. Apple nursery plants raised under warm climatic conditions of Solan (Himachal) were lifted from nurseries in first week of January and stored upto March in cold Ladakh region. Underground cellar-stored plants showed significantly higher plant survival (92-94 per cent) than greenhouse-stored plants (37-56 per cent survival). Low and constant temperature (-1.5±4.1 ºC to 10.0±1.4 ºC) and absence of light inside the cellar were favorable factors for storage of nursery plants. Lower survival rates of greenhouse-stored plants could be attributed to lower and greater fluctuations in temperature (-9.3±1.7 ºC to 25.1±1.9 ºC) inside the greenhouse. Cellar-stored plants were less subjected to freezing injury as reflected from shoot electrolyte leakage studies. The underground cellar was found effective for overwinter storage of apple nursery plants for 3 to 4 months. The method described is easy and cost-effective, and can be a satisfactory alternative to refrigerated cold storage in trans-Himalayan region with severe winters.

Keywords: Cellar; Electrolyte leakage; Freeze injury; Greenhouse; *Malus*

1. INTRODUCTION

Apple is the most widely planted fruit tree in trans-Himalayan Ladakh after apricot. The region represents great wealth of indigenous apple germplasm that vary in colour, size, flavour and texture. The popular local cultivars, *Tha* and *Mongol*, ripe in August but do not store well. However, fruit of introduced delicious cultivars ripe in late October and stored well for 4-5 months by traditional method of storage. In view of late ripening and prolong fruit storage quality, there is an increasing demand for nursery plants of delicious cultivars in Ladakh. However, nurseries of delicious cultivars are not raised locally, and the region is heavily dependent on plants raised in warmer climates of Kashmir or Himachal.

It is a common practice to lift apple nursery plants from nurseries in Himachal in late December to early January when the plants are in dormant stage. It is then airlifted to Ladakh as there is no means of surface road transport during the period. However, lifting time at the nursery does not coincide with planting season in Ladakh. The soil at planting site freeze during winter months in Ladakh, and planting is done in March-April. This necessitates need for storage of nursery plants for 3-4 months (Dec/Jan to Mar) in trans-Himalayan region. Storage of nursery plants in greenhouse is advocated in the region[1] but resulted in low plant survival after transplanting in the field. Survival per centage of these nursery plants is reduced to 40-60 per cent due to lack of a standard method for storage, which resulted in huge economic loss. Planting stock can be effectively stored in refrigerated cold-storage facilities at 30 to 38 °F and 85-90 per cent relative humidity[2]. However, power supply is a major constraint in the region and involves huge investment. To alleviate this problem, the present study was undertaken to standardize a method for storage of apple nursery plants without the need for external power supply.

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2. MATERIALS AND METHODS

2.1 Plant Materials

During two successive winters one-year-old nursery plants of apple, cultivars Vance Delicious and Red Chief grafted on seedling rootstock, were lifted from nursery bed on 17 January 2015 and 01 January 2016 from University of Horticulture and Forestry, Solan, Himachal Pradesh (elevation 1250 m). The root portions were packed in peat moss to check desiccation during handling and transport. The plants were tied in bundles, 50 plants in each, and placed in jute bags tied securely at the neck with top exposed. The plants were transported to Chandigarh and water was sprinkled regularly on the root portion to check desiccation. The plants were then airlifted from Chandigarh on 25 January 2015 and 5 January 2016. The plants were stored the same day on arrival in Ladakh.

2.2 Storage

In order to assess the effect of storage condition on survival of nursery plants, 200 plants of uniform size of each cultivar were stored under two conditions. The first lot was stored in a FRP passive solar greenhouse, and the second lot in an underground cellar (38'×12'×8', L×W×H). The packaging materials were removed on arrival and the root portion of each bundle were covered with moist soil and left till early April when conditions become favourable for planting in open field. Watering was done thrice during the storage period to keep the soil moist. Soil temperature was recorded at 10 AM at weekly interval at 10 cm depth using a soil thermometer. Air temperature was also recorded and compared with naturally open condition.

2.3 Shoot Electrolyte Leakage

The shoot electrolyte leakage test was carried out using a method similar to that described earlier[3]. Ten replicates of current year growth shoots were randomly selected from underground cellar-stored plants and two year old plants grown in shade net and naturally open condition. The shoots (0.15 g) were placed in a test tube containing 20 ml distilled water. The tubes were capped, agitated and then allowed to incubate at 25°C. The conductivity of the bathing solution was measured after 24 h using conductivity meter (SensION$^+$ EC71, HACH, Barcelona). The shoot samples were then autoclaved for 1 h to release all electrolytes. The samples were allowed to cool to room temperature before taking the second conductivity reading. The initial 24-h conductivity reading was expressed as a per centage of the second reading.

2.4 Field Performance

Three replicates of 50 nursery plants of each treatment were out-planted in the experimental field site (34°08.2'N; 77°34.3'E, elevation 3340 m) at Defence Institute of High Altitude Research in trans-Himalayan Ladakh, India in a completely randomised design. Altitude and location of the site was established using GARMIN *GPS 72*, USA. Seedlings were planted in rows (1' × 1') and per centage survival was determined in August. Plants with no leaves or live buds were treated as dead.

2.5 Statistical Analysis

The experimental results were expressed as mean ± standard deviation (SD) using statistical analysis with Statistical Program for Social Sciences (SPSS). 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 Environmental Condition

The monthly environmental condition of different storage structures along with open field condition are presented in Table 1. The temperature inside the cellar remained relatively constant. The mean maximum temperature inside the cellar was 3.2±1.2 ºC, 4.5±1.1 ºC, and 10.0±1.4 ºC in Jan, Feb and Mar, respectively. Similarly, the mean minimum temperature in the corresponding month was -1.5±4.1 ºC, 1.3±1.5 ºC, and 5.7±1.1 ºC, respectively. The soil temperature was recorded -1.4±1.1 ºC, -0.1±1.0 ºC, and 5.0±1.5 ºC in Jan, Feb and Mar, respectively. However, greater fluctuations in temperature was recorded inside the greenhouse (mean maximum = 20.3 ºC to 25.1 ºC; mean minimum = -9.3 ºC to -4.1 ºC). In comparison, the mean maximum temperature in natural outdoor was recorded 1.3±1.7 ºC, 4.3±2.9 ºC, and 9.7±2.8 ºC in Jan, Feb and Mar, respectively. Similarly, the mean minimum temperature in the corresponding month was -13.5±3.3 ºC, -9.7±2.4 ºC, and -5.1±3.8 ºC, respectively. Low and constant temperature and absence of light inside the cellar were favorable factors for storage of nursery plants. Mold growth was not observed in both the years, which is otherwise a major problem in stored plants.

Table 1. Temperature inside various storage structures and naturally open condition in trans-Himalayan Ladakh

Month		Storage Structure		Open
		Cellar	Greenhouse	
January	Max (°C)	3.2±1.2^b	20.3±1.4^c	1.3±1.7^a
	Min (°C)	-1.5±4.1^c	-9.3±1.7^b	-13.5±3.3^a
February	Max (°C)	4.5±1.1^a	24.4±2.5^b	4.3±2.9^a
	Min (°C)	1.3±1.5^c	-4.8±2.7^b	-9.7±2.4^a
March	Max (°C)	10.0±1.4^a	25.1±1.9^b	9.7±2.8^a
	Min (°C)	5.7±1.1^b	-4.1±0.4^a	-5.1±3.8^a

Values represented as mean ± SD; for each row, different lowercase letters indicate significantly different at $p<0.05$, as measured by Tukey's HSD between different groups.

3.2 Shoot Electrolyte Leakage

The shoot electrolyte leakage data is presented in Table 2. High electrolyte leakage is an index of injury caused due to frost[2,4]. The electrolyte leakage of cellar-stored plants was lower than plants grown in shade net house and open-field. Therefore, cellar-stored plants were less subjected to freezing injury. Shoot electrolyte leakage of cellar-stored plants was significantly higher in February, then decline to low values in March. The same may be due to increase in temperature from February to March.

Table 2. Shoot electrolyte leakage (per centage) in cellar-stored and field grown apple plants

Date	Cellar-stored	Shade net-grown	Open field-grown
26 Feb	41.4±11.8^b	48.8±15.1^a	55.1±18.7^a
12 Mar	34.9±7.0^{ab}	44.3±14.0^a	46.2±12.4^a
26 Mar	28.1±6.0^a	42.8±11.5^a	45.7±10.8^a

Values represented as mean ± SD; for each column, different lowercase letters indicate significantly different at $p<0.05$, as measured by Tukey's HSD between different groups.

3.3 Plant Survival in Field

Survival data for the experiments are presented in Table 3. Cellar-stored plants showed significantly higher plant survival (≥92 per cent) in both the years. Lower survival rates (37-56 per cent) of greenhouse-stored stock could be attributed to lower and greater fluctuations in temperature inside the greenhouse (Table 1). Plants exposed to strong diurnal fluctuations in soil

and air temperature, light intensity and duration, atmospheric and soil water status tend to suffer from increased tissue injury. There are number of investigations that show an increase in tissue injury with repeated freezing and thawing[5-7].

Table 3. Survival per centage of cellar-stored and greenhouse-stored apple nursery plant, cultivar Vance Delicious and Red Chief, in trans-Himalayan Ladakh

Year	Cellar-stored		Greenhouse-stored	
	Vance	Red Chief	Vance	Red Chief
2015	92.7±3.1^{c}	94.0±2.0^{c}	37.3±2.5^{a}	46.3±3.5^{b}
2016	93.3±4.2^{b}	92.0±4.0^{b}	47.0±5.0^{a}	55.7±3.8^{a}

Values represented as mean ± SD; for each row, different lowercase letters indicate significantly different at $p<0.05$, as measured by Tukey's HSD between different groups.

4. CONCLUSION

Underground cellars are commonly used in trans-Himalayan Ladakh for storage of vegetable. However, we found that the structure can effectively be used for overwinter storage of apple nursery plants for 3 to 4 months. The method described is easy and cost-effective, and can be a satisfactory alternative to refrigerated cold storage in trans-Himalayan region with severe winters.

Conflict of Interest: None

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