Australian Journal of Crop Science AJCS

AJCS 16(02):162-170 (2022) ISSN:1835-2707
doi: 10.21475/ajcs.22.16.02.3169

# Onion genotypes Red Cereole, followed by Katarina Red 3 and Katarina Red 7 are superior with respect to post harvest quality parameters

**Jagdish S Arya[1], Narendra Singh[1], Harvinder Singh[2], Anil Kant[2]***

**[1]Defence Institute of High-Altitude Research (DIHAR), C/o 56 APO – 901205, India**
**[2]Leaders Institute, 76 Park Road, Woolloongabba, Queensland 4102, Australia**
**[3]Jaypee University of Information Technology, Waknaghat, Solan, Himachal Pradesh 173234, India**

***Corresponding author: anilkantv@gmail.com**

**Abstract**

Onion bulbs of long-day genotypes, viz. Red Cereole, Katarina Red 3, Katarina Red 7, Supreme, Cyrus, Lock Roy, Legend, Wall Brown, Brown Spanish, and a local cultivar were stored for 50, 100, and 150 days in a controlled atmosphere at 2± 1 °C and 75±1% relative humidity. The experiment was laid in a randomised block design with three replicates. Dry matter, TSS, hardiness of bulb, total sugar, non-reducing sugar, and reducing sugar loss in weight (%), rotating (%) sprouting (%), sprout length (cm), incident black mold (%), and marketable bulbs (%) were recorded throughout the storage period. In all genotypes, dry matter, TSS, total sugar, and non-reducing sugars, rotting (%) sprouting (%), sprout length (cm), and incidence of black mold increased gradually during storage. In contrast, hardiness/firmness of bulb, ascorbic acid, reducing sugar, physiological losses in weight, marketable bulbs decreased gradually during the storage period. Similar patterns of increase and decrease in all the observed traits were observed for all the genotypes. Furthermore, at the genotypic level, significant variation was observed in storage potential. The genotypes Red Cereole, Katarina Red 3, and Katarina Red 7 were superior to many of the post-harvest traits. They gave the highest marketable bulb at the end of storage. Therefore, it is concluded that onion genotypes Red Cereole, Katarina Red 3, and Katarina Red 7 have good storage potential that could be stored overwinter at high altitudes. Therefore, it is recommended to cultivate these onion genotypes for long-term storage in temperate regions.

**Keywords:** Cold desert region, onion genotypes, physico-chemical, post-harvest traits, total soluble solids.
**Abbreviations:** DHA_Dehydroascorbic Acid , DM_Dry Matter, TSS_Total Soluble Solids.

## Introduction

Onion (Allium cepa var. Cepa L. family Alliaceae) is one of the most valuable vegetable crops grown worldwide. India is the second largest producer after China and ranks third in exports; however, it suffers from great fluctuations in supply and prices due to the effect of climate and weather on production and post-harvest losses. The shelf life of onion is more relevant in India because it is produced in the production hot spot states of Maharashtra, Gujarat, and Karnataka and transported to long-distance markets. Post-harvest losses may be as high as 66% due to poor postharvest management, absence of adequate cold storage or preservation facilities, and poor transport infrastructure, resulting in poor quality and shortage of onion in relation to the requirement (Adnan et al., 2014; Margaret et al., 1993).

Rotting, sprouting, physiological weight loss, and post-harvest diseases are reasons for the huge post-harvest loss reduction in marketable quality. A higher rate of respiration at room temperature generates heat, resulting in sprouting, causing loss of moisture and weight from bulbs (Petropoulos et al., 2017; Tanaka 1991; Gubb and MacTavish, 2002). Several studies have been carried out regarding onion storage at various temperatures. It was found that refrigeration temperature lowers respiration rate and inhibits sprouting and decay, which helps retain the quality and increase the shelf life of onion. Hot and humid storage conditions are suitable for the growth of black mold (Aspergillus niger) (Arowora and Adetunji, 2014; Tanaka, 1991; Yoo et al., 1989; Yang et al., 2004) bacterial soft rot (Pseudomonas gladioli) (Vintila et al., 2014; Wright, 1993) and other storage diseases in onion bulbs (Tripathi and Lawande, 2019). The quality of onion bulbs was better retained at low temperatures (0 °C).

Studies indicate that postharvest losses can be minimised by postharvest management and preharvest management, such as improved varieties and proper cultural practices. Some cultivars cannot maintain their quality for a long duration at ambient temperatures; however, some cultivars can be stored for more than six months under ambient conditions without deteriorating the quality. The selection of such long-storing cultivars could help maintain and enhance the physicochemical characteristics of onion bulbs.

Many physiological changes occur during post-harvest storage, resulting in a decline in the quality of the produce. There are two types of patterns for changing the sugar content in onion bulbs during storage. First, the sugar content changes with storage period following a regular trend, which may be monotonous increase, decrease, or a stable pattern. Second, there may be sharp fluctuations in

the concentration, with the amplitude and period of fluctuations showing no specific behaviour (Sharma and Lee, 2016). Sugar content in onion during storage depends on the type of cultivar, storage temperature, and postharvest treatments and techniques showing either a constant or fluctuating behaviour. Hence, there are conflicting reports in the literature and findings (Chope et al., 2007; Hansen, 1999). The ascorbic acid content in onion differs from cultivar to cultivar. Ascorbate oxidase is a copper-containing enzyme that oxidises ascorbic acid to dehydroascorbic acid (DHA) in the presence of molecular oxygen (Saari et al., 1995). Ascorbate oxidase is associated with rapidly growing regions in the plant and bound to cell walls and soluble protein in the cytosol. Under stress, such as pathogen or chemical exposure, ascorbate oxidase levels increase (Bielen et al., 2013; Loewus et al., 1987). Thus, ascorbic acid decreased throughout the storage period.

Although several studies on the shelf life of onion have been performed, there is no research on the storage behaviour of long-day onion cultivated in Leh-Ladakh. This motivated the researchers to conduct experiments on the shelf life of long-day onion genotypes. This study aims to understand the physicochemical changes occurring during storage of onion bulbs under controlled climatic conditions of Leh-Ladakh. The main objective is to elucidate the storage behaviour of different long-day onion genotypes.

**Results and Discussion**

***Impact of Postharvest Storage on Important Quality parameters***

***Dry Matter Content***

The observations of data indicate that the dry matter content range in different genotypes of onion was found to be from 8.03% to 14.83%, 8.21% to 15.07%, 8.33% to 15.12%, and 8.46% to 15.89% at 0, 50, 100, and 150 days of onion bulb storage (Table 1). The highest dry matter content was found in the Red Creole genotype, ranging from 14.83% to 15.89% during storage, followed by Katarina Red 3 (13.31% to 14.42%). The highest dry matter content (15.89%) was found at 150 days of storage of onion bulbs, whereas the lowest (8.03%) was found in Wall Brown at 0 days of storage. There was a significant difference in dry matter content during storage. The increase in dry matter content during storage could be attributed to the decrease in moisture content of the bulbs and increase in chemical constituents, resulting in more dry matter. Similar findings on the characterisation of stored onions and shallots by high dry matter content have been reported (Kahsay et al., 2013). Among the cultivars of bulb onions, dry matter content consisting mostly of fibre and sugars is an important quality factor determining bulb use; such high-dry-matter onions are required for dehydration.

***Hardiness of Onion Bulbs***

The hardiness of onion bulbs of different genotypes varied from 5.77 Kg/cm2 to 11.61 Kg/cm2, 5.11 Kg/cm2 to 11.53 Kg/cm2, 4.23 Kg/cm2 to 11.41 Kg/cm2, and 3.48 Kg/cm2 to 9.94 Kg/cm2 during 0, 50, 100, and 150 days of storage, respectively (Table 2). The maximum hardiness of the bulb was recorded as 11.61 kg/cm2, 11.53 kg/cm2, 11.41 and 9.94 kg/cm2 during 0, 50, 100, and 150 days of storage, respectively in the genotype Red Creole followed by Katarina Red 3 (11.09 kg/cm2, 10.75 kg/cm2, 10.01 kg/cm2, and 9.13 kg/cm2) at 0, 50, 100, and 150 days of storage, respectively. The hardness of bulbs decreased significantly during storage. Highest hardiness of the bulb was observed in fresh onion (11.61 Kg/cm2 in Red Creole) and lowest hardiness of the bulb was observed at 150 days of storage (3.48 Kg/cm2 in genotype Local cultivar). According to the findings of (Darbyshire and Henry, 1979), onions with high dry matter content are likely to be much firmer and can be stored for longer periods before shoot growth, and disease incidence reduces the marketable bulbs. Similar findings were reported by (Rutherford and Whittle, 1982) who classified cultivars by dry matter content from the highest to the lowest content that matches the ranking in terms of storage life from longest to shortest. Moreover, (Suzuki and Cutliffe, 1989) stated that higher dry matter content resulted in firmer bulbs.

***Weight loss and Rotting***

The physiological weight loss in different genotypes of onion bulbs ranged from 2.99% to 26.47% at 50 days of storage, 3.94% to 29.50% at 100 days of storage, and 8.65% to 61.28% at 150 days of storage (Table 3). The physiological loss in fresh onion bulbs was considered to be zero. The physiological loss in weight of the bulb was found to be maximum in the local cultivar (26.47%, 29.50%, and 61.28%) at 50, 100, and 150 days of storage. The lowest physiological loss in weight (2.99%, 3.94%, and 8.65%) at 50, 100, and 150 days of storage was found in the Red Creole genotype. The physiological weight loss in all genotypes increased significantly during the storage period. It was found to be lowest in Red Creole (8.65%) and highest in Local cultivar (61.28%) at 150 days of storage. Physiological loss in weight of onion bulbs during storage occurs due to moisture loss by respiration and hence depends on temperature. Therefore, weight loss decreases significantly with storage at low temperatures (Ko et al., 2002). Weight loss in onion bulbs was different in various genotypes; thus, results were observed to agree with the findings reported earlier (Kahsay et al., 2013) wherein it is reported that 'Bombay Red' and 'Melkam' varieties showed a significantly higher percentage of bulb weight loss.

The rotting percentage of the onion bulb of different genotypes varied from 0.66 % to 6.92%, 1.21% to 13.45%, and 2.58% to 30.44% at 50, 100, and 150 days of storage, respectively (Table 3). The minimum rotting percent of the bulb was recorded in Red Creole at 0%, 0.84%, and 2% at 50, 100, and 150 days of storage, respectively, followed by Katarina Red 3 at 0.83%, 1.21%, and 3.31%, and Katarina red 7 0.84%, 1.19%, and 3.63% at 50, 100, and 150 days of storage, respectively. Furthermore, the maximum rotting percentage of the bulb was in the local cultivar (6.92%, 13.45%, and 30.44% at 50, 100, and 150 days of storage). The percentage of rotting increased significantly during the storage of onion bulbs of all genotypes. Microbial spoilage is a major constraint in improving the storability of onion bulbs. They multiply and infect the bulb surface when congenital conditions prevail. Onion bulbs are affected by various postharvest diseases, such as black mold, neck rot, white rot, and soft rot. Among these, the only major postharvest disease responsible for the rotting of bulbs during storage was identified as black mold rot caused by Aspergillus niger. It is interesting to note that rotting and black mold were very low after 50 days of storage. The rotting and black mold percentages of bulbs significantly increased during 100 and 150 days of storage. The higher

rotting and black mold percentage may be due to the buildup of respiratory heat and humidity within the onion pile, creating favourable conditions for the proliferation of spoilage pathogens. Storage life can also be associated with dry matter (DM) content. This result is in accordance with a previous report where DM was also reported to be negatively correlated with the level of rotten bulbs (Rafika et al., 2006).

***Sprouting***

The data showed that the sprouting percentage in different genotypes of onion was found to be in the range of 0.67% to 7.01%, 1.00% to 16.53%, and 2.96% to 42.11% at 50, 100, and 150 days of storage (Table 4). In the genotype Red Creole, the sprouting percent was found to be minimum, which was recorded as 0.67%, 0.83 %, and 2.96% at 50,100, and 150 days of storage followed by 0.67, 1.00, 3.57% and 0.83, 1.10, 5.11% were found in the genotypes Katerina Red 3, Katerina Red 7, respectively. According to (Ghulam et al., 2013), the increasing sprouting percentage for different storage durations might be due to the increasing rate of respiration and metabolic processes.

The sprouting length in onion bulbs varied from 0.33 cm to 2.72 cm, 0.33 cm to 5.82 cm, and 1.21 to 9.00 cm during 50, 100, and 150 days of storage, respectively (Table 4). The sprouting length was found to be minimum (0.33, 0.33, and 1.21 cm) in Red Creole, followed by Katarina Red 3 (0.30, 0.47, and 1.28 cm), whereas the maximum sprouting length (2.72, 5.82, and 9.00 cm) was found at 50,100, and 150 days of storage, respectively, in the local cultivar. Sprouting was found to be augmented among all samples throughout the storage period in all genotypes. (Vintila et al., 2014) reported that sprouting was common to all genotypes of onions stored for different periods. (Kukanoor, 2005) reported that sprouting triggered the shrivelling of bulbs, resulting in the loss of marketable quality.

***Disease incidence and Marketable Bulbs***

The percentage incidence of black mold in onion bulbs ranged from 0.67% to 3.43% at 50 days of storage, 0.82% to 12.58% at 100 days of storage, and 1.80% to 15.48% at 150 days of storage (Table 5). The lowest percentage incidence of black mold 0.67%, 0.82%, and 1.80% at 50, 100, and 150 days of storage, respectively were found in genotype Red Cereole followed by Katarina Red 3 0.68, 0.82 and 1.81% and Katarina red 7 0.83, 1.34 and 1.84%, respectively. The incidence of black mold percentage was found to be a maximum of 3.43%, 12.58%, and 15.48% at 50, 100, and 150 days of storage, respectively) in the local cultivar. In fresh onion bulbs, the percentage incidence of black mold was found to be the lowest in all the genotypes, which significantly increased at 150 days of storage.

The marketable bulb percentages of different genotypes of onion were found to be in the range of 64.95% to 97.01%, 61.32% to 96.06%, and 24.43% to 88.77% during 50, 100, and 150 days of storage, respectively (Table 5). The maximum marketable bulb percentage (97.01%, 96.06%, and 88.77%) at 50, 100, and 150 days of storage, respectively, were found in the red cereole genotype. Furthermore, the minimum marketable bulb percentage was found in the local cultivar, which was recorded as 64.95%, 61.32%, and 24.43% at 50, 100, and 150 days of storage, respectively. This might be due to the genetic potential of these genotypes which produces high amounts of TSS and dry matter content that minimises weight loss, sprouting percentage, and incidence of black mold during storage.

***Impact of Postharvest storage on key metabolites composition***

***Total Soluble Solids***

The TSS content in onion bulbs ranged from 6.74% to 13.58% at 0 days of storage, 6.78% to 14.21% at 50 days of , 6.93% to 14.46%, and 7.71% to 14.79% after 150 days of storage (Table 6). The TSS was found to have maximum values of 13.58%, 14.21%, 14.46%, and 14.79% at 0, 50, 100, and 150 days of storage in the Red Creole genotype, followed by Katarina Red 3 at 11%, 11.88, 12.04, and 13%, respectively. Among all genotypes, the highest TS was found at 150 days of storage. A significant difference was observed in all genotypes during storage. TSS content was significantly influenced by different storage durations. Among the various storage durations tested, the maximum TSS was recorded at 150 days of storage, similar to the others. The higher percentage of TSS may be due to a greater loss of moisture and an increase in the dry matter content of the bulb, leading to an increase in the TSS content. These results are in close agreement with previous reports (Saimbhi and Randhawa, 1982; Patil and Kale, 1989). The lowest TSS was observed in bulbs after 0 days of storage. This may be due to the lack of metabolic reactions in freshly harvested bulbs and the high moisture content in the bulb.

***Ascorbic Acid***

The Ascorbic acid content in onion bulbs varied from 8.29 mg/100 g to 18.72 mg/100 g, 8.15 mg/100 g to 18.05 mg/100 g, 7.04 mg/100 g to 15.50 mg/100 g, and 5.78 mg/100 g to 12.55 mg/100 g during 0, 50, 100 and 150 days of storage, respectively (Table 7). The Ascorbic acid content was found maximum (18.72 mg/100 g, 18.05 mg/100 g, 15.50 mg/100 g, and 12.55 mg/100 g during 0, 50, 100 and 150 days of storage respectively) in the local cultivar followed by Cyrus (16.37 mg/100 g, 16.24 mg/100 g, 14.84 mg/100 g, 12.54 mg/100 g) and brown Spanish (16.08 mg/100 g, 15.86 mg/100 g, 14.27 mg/100 g, 12.52 mg/100 g) during 0, 50, 100, and 150 days of storage, respectively. The ascorbic acid content of the onion bulbs decreased significantly during storage. It was found to be the highest in fresh onions. There was a gradual decrease in the ascorbic acid content with increasing storage duration. This may be due to the oxidative destruction of ascorbic acid in the presence of molecular oxygen by the ascorbic acid oxidase enzyme.

***Sugar Content***

The total sugar content in different genotypes of onion was found to be in the range of 4.98% to 8.06%, 5.11% to 8.15%, 5.29% to 8.28%, and 5.98% to 8.90% at 0, 50, 100, and 150 days of onion bulb storage (Table 8). The highest total sugar content was found in the Red Creole genotype (8.90%), followed by Katarina Red 7 (8.72%) and Katarina Red 3 (8.46%) after 150 days of storage, whereas the lowest (4.98%, 5.11%, 5.29%, and 5.98%) in the Nasik Red genotype at 0,50,100, and 150 days of storage, respectively. The total sugar content increased significantly during the storage of onion bulbs in all genotypes. The reducing sugar content in different genotypes of onion was found to be in the range of 3.32% to 4.92%, 3.16% to 4.84%, 2.97% to 4.56%, and 2.56% to 3.98% at 0, 50, 100, and 150 days of storage of onion bulbs, respectively (Table S1). The maximum reducing sugar

**Table 1.** Effect of different storage durations on dry matter content.

| | | Dry matter (%) | | | |
|---|---|---|---|---|---|
| | Genotypes | 0 DOS (control) | 50 DOS | 100 DOS | 150 DOS |
| 1. | Red Cereole | 14.83±0.30$^{n}$ | 15.07±0.16$^{no}$ | 15.12±0.16$^{no}$ | 15.89±0.51$^{p}$ |
| 2. | Katarina Red 3 | 13.31±0.55$^{klm}$ | 13.53±0.51$^{lmn}$ | 13.67±0.52$^{lm}$ | 14.42±0.43$^{mn}$ |
| 3. | Katarina Red 7 | 11.22±0.40$^{fgh}$ | 11.35±0.44$^{fgh}$ | 11.85±0.31$^{fghij}$ | 12.67±0.17$^{jkl}$ |
| 4. | Supreme | 8.85±0.31$^{abcde}$ | 9.18±0.37$^{bcde}$ | 9.33±0.41$^{cde}$ | 9.70±0.28$^{e}$ |
| 5. | Cyrus | 8.84±0.21$^{abcde}$ | 9.07±0.32$^{abcde}$ | 9.42±0.30$^{de}$ | 9.73±0.20$^{e}$ |
| 6. | Lock Roy | 8.18±0.28$^{ab}$ | 8.39±0.29$^{abcd}$ | 8.44±0.27$^{abcd}$ | 8.74±0.22$^{abcde}$ |
| 7. | Legend | 8.15±0.26$^{ab}$ | 8.28±0.23$^{abc}$ | 8.44±0.12$^{abcd}$ | 8.99±0.11$^{abcde}$ |
| 8. | Wall Brown | 8.03±0.25$^{a}$ | 8.21±0.24$^{ab}$ | 8.33±0.28$^{a}$ | 8.46±0.35$^{abcd}$ |
| 9. | Brown Spanish | 12.02±0.20$^{ghij}$ | 12.02±0.39$^{ghij}$ | 12.18±0.35$^{hij}$ | 12.46±0.23$^{ijk}$ |
| 10. | Local Cultivar | 8.22±0.27$^{ab}$ | 8.32±0.25$^{abc}$ | 8.46±0.24$^{abcd}$ | 8.67±0.17$^{abcd}$ |
| 11. | Nasik Red | 10.92±0.36$^{f}$ | 11.05±0.41$^{fg}$ | 11.56±0.48$^{fghi}$ | 11.95±0.22$^{ghij}$ |
| | Range | 8.03-14.83 | 8.28-15.07 | 8.33-15.12 | 8.46-15.89 |

Values are represented as mean ± SE; for each column, different lowercase letters indicate significant differences at p<0.05, as measured by 2-sided Tukey's HSD among genotypes. Values bearing a common superscript (abcd) within the column did not vary significantly.

**Table 2.** Effect of different storage durations on Hardiness of bulb.

| S.no. | Hardness of the bulb (kg/cm$^2$) | | | | |
|---|---|---|---|---|---|
| | Genotypes | 0 DOS (control) | 50 DOS | 100 DOS | 150 DOS |
| 1. | Red Cereole | 11.61±0.50$^{o}$ | 11.53±0.49$^{o}$ | 11.41±0.62$^{o}$ | 9.94±0.14$^{nm}$ |
| 2. | Katarina Red 3 | 11.09±0.44$^{no}$ | 10.75±0.55$^{no}$ | 10.01±0.47$^{no}$ | 9.13±0.29$^{lm}$ |
| 3. | Katarina Red 7 | 10.69±0.29$^{no}$ | 10.57±0.49$^{no}$ | 10.47±0.29$^{no}$ | 9.12±0.33$^{lm}$ |
| 4. | Supreme | 7.80±0.70$^{ghij}$ | 7.34±0.78$^{hijk}$ | 4.76±0.16$^{cde}$ | 4.19±0.32$^{bcd}$ |
| 5. | Cyrus | 6.57±0.28$^{ghi}$ | 6.42±0.72$^{ghi}$ | 4.31±0.23$^{bcd}$ | 3.80±0.34$^{abc}$ |
| 6. | Lock Roy | 8.90±0.34$^{jk}$ | 8.47±0.37$^{kl}$ | 5.42±0.12$^{bcd}$ | 5.20±0.23$^{def}$ |
| 7. | Legend | 6.87±0.14$^{fgh}$ | 6.77±0.15$^{ghij}$ | 4.94±0.18$^{cde}$ | 4.90±0.10$^{cde}$ |
| 8. | Wall Brown | 7.63±0.29$^{ghi}$ | 7.53±0.48$^{ijk}$ | 4.89±0.09$^{bcd}$ | 4.79±0.20$^{cde}$ |
| 9. | Brown Spanish | 6.15±0.19$^{fgh}$ | 5.23±0.40$^{def}$ | 4.62±0.11$^{bcde}$ | 3.92±0.33$^{a}$ |
| 10. | Local Cultivar | 5.77±0.23$^{cde}$ | 5.11±0.28$^{def}$ | 4.23±0.06$^{bcd}$ | 3.48±0.19$^{ab}$ |
| 11. | Nasik Red | 6.75±0.31$^{ghij}$ | 7.55±0.58$^{ijk}$ | 5.81±0.26$^{efg}$ | 4.30±0.29$^{bcd}$ |
| | Range | 5.77-11.61 | 5.11-11.53 | 4.23-11.41 | 3.48-9.94 |

Values are represented as mean ± SE; for each column, different lowercase letters indicate significant differences at p<0.05, as measured by 2-sided Tukey's HSD among genotypes. Values bearing a common superscript (abcd) within the column did not vary significantly.

**Table 3.** Effect of different storage durations on weight loss and Rotting.

| S.no. | | Physiological loss in weight (%) | | | Rotting (%) | | |
|---|---|---|---|---|---|---|---|
| | Genotypes | 50DOS | 100DOS | 150DOS | 50DOS | 100DOS | 150DOS |
| 1. | Red Cereole | 2.99±0.08$^{a}$ | 3.94±0.21$^{a}$ | 8.65±0.42$^{bcd}$ | 0.67±0.17$^{a}$ | 0.84±0.34$^{a}$ | 2.58±0.22$^{abc}$ |
| 2. | Katarina Red 3 | 3.08±0.22$^{a}$ | 4.07±0.25$^{a}$ | 9.41±0.56$^{cdef}$ | 0.83±0.17$^{a}$ | 1.21±0.15$^{ab}$ | 3.31±0.37$^{abcd}$ |
| 3. | Katarina Red 7 | 3.75±0.16$^{a}$ | 4.90±0.16$^{ab}$ | 10.98±0.62$^{cdef}$ | 0.84±0.17$^{a}$ | 1.19±0.37$^{ab}$ | 3.63±0.37$^{bcd}$ |
| 4. | Supreme | 6.84±0.77$^{abc}$ | 12.45±1.03$^{def}$ | 31.56±3.38$^{i}$ | 4.87±0.33$^{cde}$ | 10.48±0.77$^{fg}$ | 22.89±2.75$^{l}$ |
| 5. | Cyrus | 10.27±1.02$^{cdef}$ | 13.08±1.17$^{ef}$ | 35.77±2.97$^{j}$ | 5.43±0.42$^{de}$ | 11.84±0.53$^{fgh}$ | 21.85±1.20$^{kl}$ |
| 6. | Lock Roy | 11.05±0.36$^{cdef}$ | 11.26±0.86$^{def}$ | 35.41±1.81$^{j}$ | 4.50±0.19$^{cde}$ | 9.41±0.35$^{f}$ | 19.90±1.24$^{jk}$ |
| 7. | Legend | 3.82±0.32$^{a}$ | 8.62±0.86$^{bcd}$ | 13.55±0.63$^{f}$ | 0.87±0.19$^{a}$ | 9.99±0.29$^{f}$ | 16.61±1.05$^{i}$ |
| 8. | Wall Brown | 10.32±0.20$^{cdef}$ | 12.80±0.99$^{def}$ | 31.10±1.81$^{i}$ | 4.83±0.11$^{cde}$ | 13.40±1.14$^{h}$ | 25.60±1.61$^{m}$ |
| 9. | Brown Spanish | 10.54±0.06$^{cdef}$ | 12.58±0.45$^{def}$ | 36.88±1.55$^{j}$ | 6.31±0.27$^{e}$ | 12.60±0.50$^{gh}$ | 14.29±1.19$^{n}$ |
| 10. | Local Cultivar | 26.47±1.22$^{h}$ | 29.50±1.56$^{hi}$ | 61.28±2.86$^{k}$ | 6.92±0.28$^{e}$ | 13.45±0.50$^{f}$ | 30.44±0.80$^{h}$ |
| 11. | Nasik Red | 8.99±0.85$^{cde}$ | 12.07±0.91$^{def}$ | 22.04±1.66$^{g}$ | 5.05±0.47$^{cde}$ | 10.03±0.66$^{f}$ | 18.85±1.30$^{ij}$ |
| | Range | 2.99-26.47 | 3.94-29.50 | 8.65-61.28 | 0.67-6.92 | 0.84-13.45 | 2.58-30.44 |

Values are represented as mean ± SE; for each column, different lowercase letters indicate significant differences at p<0.05, as measured by 2-sided Tukey's HSD among genotypes. Values bearing a common superscript (abcd) within the column did not vary significantly.

**Table 4.** Effect of different storage durations on sprouting.

| S.no. | | Sprouting (%) | | | Sprouting length (cm) | | |
|---|---|---|---|---|---|---|---|
| | Genotypes | 50DOS | 100DOS | 150DOS | 50DOS | 100DOS | 150DOS |
| 1. | Red Cereole | 0.67±0.17$^{a}$ | 0.83±0.29$^{ab}$ | 2.96±0.34$^{abcd}$ | 0.33±0.09$^{a}$ | 0.33±0.06$^{a}$ | 1.21±0.06$^{bc}$ |
| 2. | Katarina Red 3 | 0.67±0.17$^{a}$ | 1.00±0.33$^{a}$ | 3.59±0.43$^{cd}$ | 0.30±0.06$^{a}$ | 0.47±0.09$^{ab}$ | 1.28±0.11$^{bc}$ |
| 3. | Katarina Red 7 | 0.83±0.17$^{a}$ | 1.10±0.29$^{ab}$ | 5.11±0.26$^{de}$ | 0.27±0.09$^{a}$ | 0.34±0.09$^{a}$ | 1.75±0.24$^{c}$ |
| 4. | Supreme | 2.20±0.23$^{abc}$ | 10.70±0.69$^{h}$ | 15.73±1.14$^{i}$ | 1.20±0.10$^{bc}$ | 4.13±0.37$^{ef}$ | 5.99±0.56$^{ijk}$ |
| 5. | Cyrus | 2.87±0.24$^{abcd}$ | 9.86±0.46$^{ij}$ | 18.32±1.21$^{j}$ | 1.29±0.15$^{bc}$ | 4.59±0.35$^{fg}$ | 6.50±0.39$^{jk}$ |
| 6. | Lock Roy | 3.07±0.21$^{abcd}$ | 8.03±0.13$^{hi}$ | 16.14±1.12$^{ij}$ | 1.61±0.20$^{c}$ | 4.98±0.20$^{gh}$ | 7.44±0.50$^{l}$ |
| 7. | Legend | 1.34±0.17$^{abc}$ | 1.96±0.15$^{abc}$ | 6.33±0.28$^{ef}$ | 0.34±0.09$^{a}$ | 2.51±0.04$^{d}$ | 3.69±0.16$^{e}$ |
| 8. | Wall Brown | 3.82±0.23$^{cd}$ | 9.38±0.48$^{ij}$ | 14.63±0.76$^{i}$ | 1.66±0.25$^{c}$ | 5.37±0.47$^{ghi}$ | 7.44±0.36$^{l}$ |
| 9. | Brown Spanish | 3.62±0.23$^{cd}$ | 8.34±0.39$^{hi}$ | 32.19±1.58$^{k}$ | 1.37±0.12$^{c}$ | 5.65±0.20$^{hi}$ | 8.41±0.32$^{m}$ |
| 10. | Local Cultivar | 7.01±0.30$^{ef}$ | 16.53±0.88$^{ij}$ | 42.11±2.70$^{l}$ | 2.72±0.17$^{d}$ | 5.82±0.22$^{ij}$ | 9.00±0.35$^{m}$ |
| 11. | Nasik Red | 3.38±0.10$^{bcd}$ | 7.56±0.53$^{hi}$ | 14.20±0.69$^{i}$ | 1.11±0.07$^{abc}$ | 4.70±0.33$^{fg}$ | 6.73±0.48$^{kl}$ |
| | Range | 0.67-7.01 | 0.83-16.53 | 2.96-42.11 | 0.33-2.72 | 0.33-5.82 | 1.21-9.00 |

Values are represented as mean ± SE; for each column, different lowercase letters indicate significant differences at p<0.05, as measured by 2-sided Tukey's HSD among genotypes. Values bearing a common superscript (abcd) within the column did not vary significantly.

**Table 5.** Effect of different storage durations on Incidence of black mold and Marketable bulb.

| S.no. | Genotypes | Incidence of black mold | | | Marketable bulb (%) | | |
|---|---|---|---|---|---|---|---|
| | | 50DOS | 100DOS | 150DOS | 50DOS | 100DOS | 150DOS |
| 1. | Red Cereole | 0.67±0.17$^{a}$ | 0.82±0.32$^{ab}$ | 1.80±0.11$^{ab}$ | 97.01±0.08$^{m}$ | 96.06±0.21$^{m}$ | 88.77±0.35$^{l}$ |
| 2. | Katarina Red 3 | 0.68±0.17$^{a}$ | 0.82±0.32$^{ab}$ | 1.81±0.11$^{ab}$ | 96.92±0.22$^{m}$ | 95.93±0.25$^{m}$ | 87.28±0.36$^{kl}$ |
| 3. | Katarina Red 7 | 0.83±0.17$^{a}$ | 1.34±0.17$^{ab}$ | 1.80±0.23$^{ab}$ | 96.25±0.16$^{m}$ | 95.10±0.16$^{m}$ | 85.38±0.68$^{ijkl}$ |
| 4. | Supreme | 1.07±0.07$^{ab}$ | 3.74±0.17$^{abc}$ | 8.42±1.25$^{f}$ | 83.68±0.81$^{hijk}$ | 82.68±0.09$^{hijk}$ | 45.55±5.45$^{c}$ |
| 5. | Cyrus | 1.20±0.12$^{ab}$ | 4.45±0.12$^{ab}$ | 12.43±1.04$^{g}$ | 84.29±1.34$^{hijkl}$ | 76.74±0.26$^{fg}$ | 42.38±4.17$^{c}$ |
| 6. | Lock Roy | 1.90±0.21$^{ab}$ | 5.73±0.34$^{cdef}$ | 13.07±1.40$^{g}$ | 84.46±0.55$^{hijkl}$ | 80.66±0.62$^{ghi}$ | 44.69±0.61$^{c}$ |
| 7. | Legend | 1.40±0.31$^{ab}$ | 6.03±0.20$^{cdef}$ | 12.16±0.87$^{g}$ | 96.18±0.32$^{m}$ | 81.38±0.72$^{ghij}$ | 69.84±1.43$^{e}$ |
| 8. | Wall Brown | 2.07±0.18$^{ab}$ | 8.11±0.44$^{ef}$ | 13.55±1.63$^{g}$ | 84.19±0.61$^{hijkl}$ | 75.08±1.86$^{f}$ | 43.30±0.52$^{c}$ |
| 9. | Brown Spanish | 2.00±0.12$^{ab}$ | 7.53±0.68$^{def}$ | 12.35±1.45$^{g}$ | 80.14±0.73$^{gh}$ | 74.82±0.95$^{f}$ | 32.68±0.42$^{b}$ |
| 10. | Local Cultivar | 3.43±0.46$^{abc}$ | 12.58±1.57$^{g}$ | 15.48±1.31$^{g}$ | 64.95±0.77$^{d}$ | 61.32±1.30$^{d}$ | 24.43±3.66$^{a}$ |
| 11. | Nasik Red | 1.07±0.07$^{ab}$ | 4.56±0.60$^{bcde}$ | 8.36±1.03$^{f}$ | 85.96±1.04$^{jkl}$ | 79.93±0.75$^{gh}$ | 64.34±0.01$^{d}$ |
| | Range | 0.67-3.43 | 0.82-12.58 | 1.80-15.48 | 64.95-97.01 | 61.32-96.06 | 24.43-88.77 |

Values are represented as mean ± SE; for each column, different lowercase letters indicate significant differences at p<0.05, as measured by 2-sided Tukey's HSD among genotypes. A value bearing a common superscript (abcd) within the column does not vary significantly.

**Table 6.** Effect of different storage durations on total soluble solids (TSS).

| S.no. | | Total soluble solids (TSS, %) | | | |
|---|---|---|---|---|---|
| | Genotypes | 0 DOS (control) | 50 DOS | 100 DOS | 150 DOS |
| 1. | Red Cereole | 13.58±0.48$^{lm}$ | 14.21±0.56$^{lmn}$ | 14.46±0.69$^{mn}$ | 14.79±0.43$^{n}$ |
| 2. | Katarina Red 3 | 11.30±0.18$^{ijk}$ | 11.88±0.52$^{jk}$ | 12.04±0.48$^{k}$ | 13.37±0.44$^{l}$ |
| 3. | Katarina Red 7 | 10.56±0.35$^{hi}$ | 10.59±0.33$^{hi}$ | 10.85±0.41$^{hij}$ | 12.15±0.08$^{k}$ |
| 4. | Supreme | 8.50±0.38$^{def}$ | 8.62±0.30$^{ef}$ | 8.69±0.32$^{ef}$ | 9.09±0.36$^{fg}$ |
| 5. | Cyrus | 6.77±0.14$^{ab}$ | 6.92±0.11$^{a}$ | 6.97±0.09$^{a}$ | 9.10±0.34$^{fg}$ |
| 6. | Lock Roy | 7.39±0.36$^{abcd}$ | 7.45±0.43$^{abcd}$ | 7.49±0.39$^{abcd}$ | 8.27±0.18$^{cdef}$ |
| 7. | Legend | 7.18±0.63$^{abc}$ | 7.50±0.32$^{abcd}$ | 7.34±0.71$^{abc}$ | 8.29±0.23$^{cdef}$ |
| 8. | Wall Brown | 6.78±0.03$^{a}$ | 6.93±0.17$^{ab}$ | 6.93±0.20$^{ab}$ | 7.71±0.33$^{abcde}$ |
| 9. | Brown Spanish | 11.23±0.06$^{ijk}$ | 11.28±0.04$^{ijk}$ | 11.52±0.06$^{ijk}$ | 11.50±0.17$^{ijk}$ |
| 10. | Local Cultivar | 7.28±0.26$^{abc}$ | 7.32±0.28$^{abc}$ | 7.44±0.32$^{abcd}$ | 7.92±0.28$^{bcde}$ |
| 11. | Nasik Red | 9.92±0.19$^{gh}$ | 10.02±0.10$^{gh}$ | 10.11±0.22$^{gh}$ | 10.72±0.34$^{hi}$ |
| | Range | 6.77-13.58 | 6.92-14.21 | 6.93-14.46 | 7.71-14.79 |

Values are represented as mean ± SE; for each column, different lowercase letters indicate significant differences at p<0.05, as measured by 2-sided Tukey's HSD among genotypes. Values bearing a common superscript (abcd) within the column did not vary significantly.

**Table 7.** Effect of different storage durations on ascorbic acid.

| S.no. | Ascorbic acid (mg/100 g bulb) | | | | |
|---|---|---|---|---|---|
| | Genotypes | 0 DOS (control) | 50 DOS | 100 DOS | 150 DOS |
| 1. | Red Cereole | 13.07±0.22$^{efgh}$ | 13.09±0.17$^{efgh}$ | 11.77±0.59$^{def}$ | 7.58±0.68$^{bc}$ |
| 2. | Katarina Red 3 | 13.12±0.19$^{efgh}$ | 13.08±0.22$^{efgh}$ | 11.98±0.97$^{defg}$ | 8.52±0.74$^{bc}$ |
| 3. | Katarina Red 7 | 14.11±0.06$^{hij}$ | 13.75±0.16$^{hi}$ | 12.98±0.64$^{efgh}$ | 8.77±0.28$^{c}$ |
| 4. | Supreme | 15.69±0.45$^{jkl}$ | 15.65±0.48$^{jkl}$ | 14.11±1.25$^{hij}$ | 10.30±0.95$^{d}$ |
| 5. | Cyrus | 16.37±0.37$^{kl}$ | 16.24±0.33$^{kl}$ | 14.84±0.40$^{ijk}$ | 12.54±0.55$^{def}$ |
| 6. | Lock Roy | 15.57±0.53$^{jk}$ | 15.54±0.55$^{jk}$ | 13.61±0.83$^{ghi}$ | 11.39±0.87$^{de}$ |
| 7. | Legend | 8.29±0.21$^{bc}$ | 8.15±0.13$^{bc}$ | 7.04±0.14$^{ab}$ | 5.78±0.29$^{a}$ |
| 8. | Wall Brown | 15.83±0.60$^{kl}$ | 15.81±0.61$^{kl}$ | 13.35±0.48$^{fghi}$ | 10.58±0.49$^{d}$ |
| 9. | Brown Spanish | 16.08±0.62$^{m}$ | 15.86±0.73$^{m}$ | 14.27±0.60$^{l}$ | 12.52±0.55$^{efgh}$ |
| 10. | Local Cultivar | 18.72±0.33$^{n}$ | 18.05±0.77$^{n}$ | 15.50±0.56$^{m}$ | 12.55±0.69$^{de}$ |
| 11. | Nasik Red | 12.78±0.35$^{efgh}$ | 12.71±0.40$^{efgh}$ | 10.55±0.56$^{d}$ | 7.22±0.38$^{abc}$ |
| | Range | 8.29-18.72 | 8.14-18.05 | 7.04-15.50 | 5.78-12.55 |

Values are represented as mean ± SE; for each column, different lowercase letters indicate significant differences at p<0.05, as measured by 2-sided Tukey's HSD among genotypes. Values bearing a common superscript (abcd) within the column did not vary significantly.

**Table 8.** Effect of different storage durations on Total sugar.

| S.no. | Total sugar (%) | | | | |
|---|---|---|---|---|---|
| | Genotypes | 0 DOS (control) | 50 DOS | 100 DOS | 150 DOS |
| 1. | Red Cereole | 8.06±0.16$^{qrst}$ | 8.15±0.14$^{qrstu}$ | 8.28±0.21$^{qrstuv}$ | 8.90±0.07$^{v}$ |
| 2. | Katarina Red 3 | 7.36±0.14$^{klmnop}$ | 7.49±0.15$^{lmnopq}$ | 7.58±0.13$^{mnopq}$ | 8.46±0.13$^{tuv}$ |
| 3. | Katarina Red 7 | 7.62±0.32$^{nopqr}$ | 7.78±0.33$^{pqrs}$ | 8.35±0.14$^{stuv}$ | 8.72±0.08$^{uv}$ |
| 4. | Supreme | 7.47±0.18$^{lmnopq}$ | 7.61±0.16$^{nopqr}$ | 7.76±0.16$^{pqrs}$ | 8.10±0.13$^{qrstu}$ |
| 5. | Cyrus | 6.56±0.35$^{fghi}$ | 6.69±0.35$^{ghij}$ | 7.02±0.25$^{ijklmno}$ | 7.64±0.09$^{nopqr}$ |
| 6. | Lock Roy | 7.52±0.42$^{lmnopq}$ | 7.65±0.41$^{nopqr}$ | 7.80±0.44$^{pqrs}$ | 8.58±0.21$^{tuv}$ |
| 7. | Legend | 5.97±0.17$^{cdef}$ | 6.19±0.18$^{defg}$ | 6.91±0.10$^{ijklm}$ | 7.33±0.13$^{jklmnop}$ |
| 8. | Wall Brown | 7.31±0.16$^{jklmnop}$ | 7.49±0.17$^{lmnopq}$ | 7.69±0.24$^{opqrs}$ | 8.11±0.18$^{qrstu}$ |
| 9. | Brown Spanish | 6.71±0.39$^{qhijk}$ | 6.88±0.35$^{hijkl}$ | 6.98±0.43$^{ijklmn}$ | 7.56±0.28$^{mnopq}$ |
| 10. | Local Cultivar | 5.38±0.07$^{abc}$ | 5.56±0.07$^{abcd}$ | 5.85±0.18$^{bcde}$ | 6.26±0.20$^{efgh}$ |
| 11. | Nasik Red | 4.98±0.08$^{a}$ | 5.11±0.06$^{a}$ | 5.29±0.03$^{ab}$ | 5.98±0.11$^{cdef}$ |
| | Range | 4.98-8.06 | 5.11-8.15 | 5.29-8.28 | 5.98-8.90 |

Values are represented as mean ± SE; for each column, different lowercase letters indicate significant differences at p<0.05, as measured by 2-sided Tukey's HSD among genotypes. Values bearing a common superscript (abcd) within the column did not vary significantly.

content (4.92%, 4.84%, 4.56%, and 3.98%) after 50, 100, and 150 days of storage, respectively, was found in the Red Creole genotype, followed by Katarina Red 7(4.77%, 4.67%, 4.38%, and 3.95% at 0,50,100, and 150 days of storage, respectively). The highest reducing sugar content (4.92% in Red Creole, 4.77% in Katarina Red 7) was found in fresh onion bulbs, whereas the lowest (3.98% in Red Creole, 3.95% in Katarina Red 7) was found at 150 days of storage. The reducing sugar content decreased significantly during 150 days of storage.

The non-reducing sugar content in onion bulbs varied from 1.66% to 3.63%, 1.95% to 3.93%, 2.32% to 4.32%, and 3.37% to 5.62% at 0, 50, 100, and 150 days of storage, respectively (Table S2). It was found to be maximum (3.63%, 3.93%, 4.32%, and 5.62%) at 0, 50, 100, and 150 DOS, respectively, in the genotype Lock Roy, followed by Brown Spanish 3.33%, 3.58%, 3.97%, and 4.98% at 0, 50, 100, and 150 DOS, respectively, and Red Creole 3.13%, 3.41%, 3.87%, and 4.92%) at 0, 50, 100 and 150 DOS respectively). A significant variation was observed in the non-reducing sugar content during storage. The highest non-reducing sugar content was recorded after 150 d of storage of onion bulbs. The increase in total sugar content could be due to the enzymatic hydrolysis of fructans to fructose and glucose during the storage period (Shivakumar and Chandrashekar, 2014). All genotypes showed a decreasing trend in reducing sugars during all storage durations. The differences between the varieties and storage durations were found to be significant. The decreasing trend may be due to the conversion of reducing sugars to starch during storage at low temperatures (Kukanoor, 2005; Bogevska et al., 2016). It wasobserved that the cultivar, postharvest treatments, and temperature can affect sugar content during storage, showing either a constant or an unstable pattern (Chope et al., 2007). The sugar content may be correlated with other physiological factors, such as dormancy break and sprouting (Sharma and Lee, 2016). There are two types of sugar content behaviour. According to the first one, the concentration of sugar changes with storage time following a regular pattern, such as a monotonous increase, decrease, or stable behaviour. Another type of behaviour consists of strong fluctuations in the sugar content, with the amplitude and period of fluctuations showing no regular pattern (Sharma et al., 2015).

## Materials and methods

### *Conduction of study*

The present study was conducted during two consecutive cropping seasons at the Vegetable Research Unit of the Defense Institute of High Altitude Research, Defense Research and Development Organization, which lies at

latitude 34°8'16.119' 'N, longitude 77°34'19.2216 '' E at an elevation of 3500 m msl in Leh-Ladakh, India. The climate of the area is typically dry temperate, with extreme fluctuations in temperature, and precipitation is negligible.

***Plant material***

The experimental material consisted of nine long-day genotypes and one local cultivar of onion: Red Creole, Katarina Red 3, Katarina Red 7, Supreme, Cyrus, Lock Roy, Legend, Wall Brown, Brown Spanish, Local Cultivar, and Nasik Red. The seeds were sown in trenches with 5 cm spacing between lines during the first week of April, and all standard agronomic practices recommended for onion cultivation were carried out. After 60 days, when the seedlings reached the optimum set/baby bulb size, they were harvested and cured in the shade for one month. They were stored at 2±1 0C and 75±2 % relative humidity in an onion store. Sets were planted to produce mature onion bulbs using standard agronomic practices. The crop was harvested at maturity when 70 % of the plants showed drying and falling of their tops. The plants were pulled along with leaves and kept for three days in the field for curing. The dry aerial parts were removed with sharp clean knives leaving a 2.5 cm top above the bulb. These bulbs were kept under 50 % shade for curing for 20 days. The cured onion bulbs were sorted out; any diseased or damaged bulbs were discarded before storage, and 5 kg of healthy bulbs from each treatment were packed in thin gunny bags and stored for storage. Bulbs were stored under controlled atmosphere (CA) conditions (2± 1 °C and 75±1% relative humidity).

***Experimental design***

The experiment was conducted in a randomised block design with three replicates. The observations were recorded at 50, 100, and 150 days of storage for the traits, such as physiological loss in weight (%), rotation (%), sprouting (%), sprout length (cm), incidence of black mold (%), and marketable bulbs (%).

***Dry matter (%)***

Bulbs were randomly selected from each treatment and cut into small pieces using a stainless steel knife. A known weight of the sample was dried in a hot air oven at 60 °C until a constant weight was obtained. The percentage of dry matter was calculated using the following formula: Dry matter percent = (Dry weight of sample)/(Fresh weight of sample)×100

***Total Soluble Solids (%)***

The total soluble solids (TSS) of onions were determined using a hand refractometer (Attago, Japan). The values were expressed as the percentage of total soluble solids of the bulbs.

***Hardness of the bulb (kg/cm2)***

The hardness of the onion bulbs was measured using a hand penetrometer (Fruit Pressure Tester, Make: Effegi, Model: PT 327), and the pressure required to penetrate the bulb was recorded in kg/cm2.

***Ascorbic Acid (mg/100 g)***

Vitamin C (ascorbic acid) in the onion bulb was calculated using the titrimetric method (AOAC, 2005). A fresh onion bulb (100 g) was crushed the whole material into a pestle and mortar by adding 100 ml 2 per cent oxalic acid solution. The whole content was finally transferred into a pre-weighed beaker, and the weight of the crushed slurry was recorded on a digital balance. Twenty grams of crushed slurry was transferred into a 100 ml capacity conical flask and the volume was made up to 100 ml by adding one per cent oxalic acid solution. The content of the conical flask was filtered using filter paper, and the filtrate was collected into another flask. The filtrate (5 ml) of each flask was taken and the whole content of the conical flask was titrated against the dye solution (2, 6-dichloro phenol endophenol) until the end point (pink colour) was achieved, and the titer value was noted. A 5 ml standard ascorbic acid solution was placed in another conical flask and the whole content was titrated against the dye solution until the end point was obtained. The results were expressed as milligrammes of ascorbic acid per 100 g of fresh sample.

***Total Sugars (%)***

Total sugar was measured using the phenol-sulfuric acid method (Dubois et al., 1951). Water (0.1 ml of sample, water was added to a volume of 2 ml. To this solution 0.05 ml phenol reagent and 5 ml sulfuric acid were added rapidly one after another and allowed to remain at room temperature for 30 min. The absorbance was recorded at 490 nm against a reagent blank. A standard curve using an aqueous stock solution containing 10-120 µg of D-glucose was plotted to estimate total sugar in the samples.

***Estimation of Reducing Sugars***

Reducing sugar (%) was determined using the dinitrosalicylic acid method. One gram of sample was taken and crushed properly in a mortar and pestle. It was transferred to a test tube, and the volume was made up to 1 ml with distilled water. Then, 3 ml DNS reagent was added and incubated in a boiling water bath for 20 min and cooled for 5 min at room temperature. The sample was then diluted to make up 20 ml (necessary to obtain a percentage between 20% and 80%). A glucose standard curve was produced in the range of 0.25-6.0 mg of glucose per ml using the same procedure. The absorbance was recorded at 540 nm against the blank reagent when the colour stability developed until 72 h.

***Non-reducing sugar (%)***

The percentage of non-reducing sugar was obtained by subtracting the values of reducing sugar from that of total sugar and multiplying it with 0.95, as described below.

Nonreducing sugar (%)=(Total sugar-reducing sugar)×0.95

Weight Loss (%)

The weight of the bulbs was measured using an electronic balance. The cumulative weight loss of the bulbs was calculated and expressed as percent weight loss.

Weight loss (%) = ((W0-W1-W2-W3))/W0×100

where W0 is the initial weight of the bulbs, W1 is the weight loss at 50 days of storage, W2 is the weight loss at 100 days of storage, and W3 is the weight loss at 150 days of storage.

***Rotting (%)***

The weight of the rotted bulbs at the end of 50, 100, and 150 days of storage (DOS) was recorded under each storage condition, and the rotting percentage was calculated using the formula.

Rotting (%) = (Weight of rotted bulbs)/(Initial weight of the bulbs)×100

***Sprouting (%)***

To determine the sprouting percentage on stipulated days of storage, the bulbs showing a sprout were separated from the lot and weighed on an electronic balance. The sprouting percentage, which indicates the weight of the bulbs sprouted at 50, 100, and 150 days of storage (DOS) was calculated.

Sprouting percentage = (Weight of sprouted bulbs)/(Initial weight of the bulbs)×100

***Sprout length (cm)***

Five sprouted bulbs were randomly selected, and the length of the sprouts in each bulb was measured. The mean length of the sprouts was expressed in centimetres.

***Incidence of black mold (%)***

The incidence of black mold was expressed as the percentage of bulbs affected per 100 bulbs.

***Marketable bulbs (%)***

At the end of the storage period (150 DOS), the rotted and sprouted bulbs were separated, and the weight of healthy bulbs was recorded. The recovery of marketable bulbs was calculated using the following formula:

Marketable bulbs (%) = (Weight of the healthy bulbs obtained)/(Initial weight of the bulbs stored)×100

***Statistical Analysis***

All statistical analyses were performed using the statistical package "SPSS" for Windows Version 21. The least significant difference between mean values was calculated using Duncan's multiple range test (DMRT) at the 5% significance level.

Conclusion

Different physiological and biochemical changes occur during the storage period in all genotypes, causing significant post-harvest storage deterioration and reduce the marketable bulb quality. It can be concluded that the quality of the stored material depends on the genetic potential of the studied genotypes and storage duration. The highest dry matter and total soluble solids were observed in the Red Cereole genotype, which increased with the number of days of storage, whereas ascorbic acid was the highest in the Local cultivar. Total sugar and reducing sugar were highest in red cereole, which decreased with the increase in days of storage. The least weight loss, rotting, the incidence of black mold, sprouting was observed in red cereole, and the highest marketable bulb yield was observed in red cereole. Therefore, among all the studied genotypes, Red Cereole, Katarina Red 3, and Katarina Red 7 were characterised as having a longer storage life with the highest proportion of marketable bulbs.

**References**


Adnan KM, Rahman MM, Sarker SA (2014) Marketing channels and post harvest practices of onion: a case of Bogra and Joypurhat District in Bangladesh. Universal Journal of Agricultural Research. 2(2): 61-66.

AOAC. (2005) Association of Official Analytical Chemists AOAC Official Methods of Analysis, 18th ed. Association of Official Analytical Chemists, Gaithersburg, MD, USA.

Arowora KA, Adetunji CO (2014) Antifungal Effects of Crude Extracts of Moringa oleifera on Aspergillus niger v. tieghem Associated with Post Harvest Rot of Onion Bulb. SMU Med J. 1(2): 214-23.

Bielen A, Remans T, Vangronsveld J, Cuypers A (2013) The influence of metal stress on the availability and redox state of ascorbate, and possible interference with its cellular functions. Int J Mol Sci.14(3):6382-413.

Bogevska Z, Agic R, Popsimonova G, Davitkovska M, Iljovski I (2016) Reducing and

total sugar content in onion during storage in the Republic of Macedonia. Agro Know J. 17(1): 37-46.

Chope GA, Terry LA, White PJ (2007) The effect of the transition between controlled atmosphere and regular atmosphere storage on bulbs of onion cultivars SS1, Carlos and Renate. Postharvest Biol Tec. 44(3): 228-239.

Darbyshire B, Henry RJ (1979) The association of fructans with high percentage dry weight in onion cultivars suitable for dehydrating. J Sci Food Agr. 30(11): 1035-1038.

Dubois M, Gilles K, Hamilton JK, Rebers PA, Smith F (1951) Colorimetric determination of reducing and nonreducing saccharides. Nature, 168: 167-169.

Ghulam N, Abdu, R, Muhammad S, Abbas SJ, Imran A (2013) Influence of curing methods and storage conditions on the post-harvest quality of onion bulbs. Pakistan J Bot. 45(2): 455-460.

Gubb IR, MacTavish HS (2002) Onion Pre-and Postharvest Considerations. Allium crop science: recent advances. p233.

Hansen SL (1999) Content and composition of dry matter in onion (Allium cepa L.) as influenced by developmental stage at time of harvest and long-term storage. Acta Agr Scand B-S P. 49(2): 103-109.

Kahsay Y, Abay F, Belew D (2013) Intra row spacing effect on shelf life of onion varieties (Allium cepa L.) at Aksum, Northern Ethiopia. Journal of Plant Breeding and Crop Science. 4(6): 127-136.

Ko SS, Chang WN, Wang JF, Cherng SJ, Shanmugasundaram S (2002) Storage variability among short-day onion cultivars under high temperature and high relative humidity, and its relationship with disease incidence and bulb characteristics. J Am Soc Hortic Sci. 127(5): 848-854.

Kukanoor L (2005) Post-Harvest Studies in Onion PhD thesis, Department of Horticulture, College of Agriculture, Dharwad University of Agricultural Sciences, Dharwad. p19

Loewus FA, Loewus MW, Seib PA (1987) Biosynthesis and metabolism of ascorbic acid in plants. Crit Rev Plant Sci. 5(1): 101-119.

Mergaert J, Verdonck L, Kersters K (1993) Transfer of erwinia-ananas (synonym, erwinia-uredovora) and erwinia-stewartii to the genus pantoea emend as pantoea-ananas (serrano 1928) comb-nov and

pantoea-stewartii (smith 1898) comb-nov, respectively, and description of pantoea-stewartii subsp indologenes subsp nov. Int J Syst Bacteriol. 43(1): 162-173.

Patil RS, Kale PN (1989) Screening of onion cultivars for storage quality. Vegetable Science. 16: 56-61.

Petropoulos SA, Ntatsi G, Ferreira IC (2017) Long-term storage of onion and the factors that affect its quality: A critical review. Food Rev Int. 33(1):62-83.

Rafika SB, Mejda DR, Mohamed BK, Hatem C (2006) Onion storage ability and an inventory of onion post-harvest fungi in Tunisia. Trop Sci. 46(2): 105-112.

Rutherford PP, Whittle R (1982) The carbohydrate composition of onions during long term cold storage. J Hortic Sci. 57(3): 349-356.

Saari NAZAMID, Fujita S, Miyazoe R, Okugawa M (1995) Distribution of ascorbate oxidase activities in the fruits of family cucurbitaceae and some of their properties. J Food Biochem. 19(4): 321-327.

Saimbhi MS, Randhawa KS (1982) Losses in white onion variety Punjab-48 under ordinary storage conditions as influenced by bulb size. Journal of research-Punjab Agricultural University.19: 198-190.

Sharma K, Asnin L, Ko EY, Lee ET, Park SW (2015) Phytochemical composition of onion during long-term storage. Acta Agr Scand B-S P. 65(2): 150-160.

Sharma K, Lee YR (2016) Effect of different storage temperature on chemical composition of onion (Allium cepa L.) and its enzymes. J Food Sci Technol. 53(3): 1620-1632.

Shivakumar, Chandrashekar SY (2014) Physio-chemical changes during post-harvest handling of onion (Allium cepa L.) A review. Agr Rev. 35(3): 225-232.

Suzuki M, Cutcliffe JA (1989) Fructans in onion bulbs in relation to storage life. Can J Plant Sci. 69(4): 1327-1333.

Tanaka K (1991) Studies on the Black Mold Disease of Onion Bulbs Caused by Aspergillusniger van Tieghem. Bulletin of the Faculty of Agriculture Saga University Bull. 70: 1-54.

Tripathi PC, Lawande KE (2019). Onion storage in tropical region—a review. Current Horticulture:15.

Vintila M, Niculescu FA, Romas M (2014) Technical aspects regarding the preservation of dry onions in different storage conditions. Bulletin UASVM Food Science and Technology. 71(2): 195-199.

Wright PJ (1993) Effects of nitrogen fertiliser, plant maturity at lifting, and water during field-curing on the incidence of bacterial soft rot of onions in store. New Zeal J Crop Hort 21: 377-381.

Yoo KS, Andersen CR, Pike LM (1989) Determination of postharvest losses and storage life of' Texas Grano 1015Y'onion. Journal of the Rio Grande Valley Horticultural Society. 42: 45-50.

Yang J, Meyers KJ, van der Heide J, Liu RH (2004). Varietal differences in phenolic content and antioxidant and antiproliferative activities of onions. J Agr Food Chem. 52(22): 6787-6793.