Characterization and Evaluation of Onion (*Allium cepa* L.) Germplasm at Leh, trans-Himalaya, India

Thesis submitted in fulfilment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

By

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DECLARATION

I hereby declare that the work reported in the PhD thesis titled **"Characterization and Evaluation of Onion (*Allium cepa* L.) Germplasm at Leh, trans-Himalaya, India"** submitted at **Jaypee University of Information Technology, Waknaghat, Solan, India** is an authentic record of my work carried out under the supervision of Dr. **Anil Kant** and **Dr. Narendra Singh**. I have not submitted this work elsewhere for the award of any other degree or diploma.

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SUPERVISOR'S CERTIFICATE

This is to certify that the work reported in the PhD thesis titled **"Characterization and Evaluation of Onion (*Allium cepa* L.) Germplasm at Leh, trans-Himalaya, India"** submitted by **Jagdish Singh Arya** at **Jaypee University of Information Technology, Waknaghat, Solan, India** is a bonafide record of his original work carried out under our supervision. This work has not been submitted elsewhere for any other degree or diploma.

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CHAPTER 1

INTRODUCTION

Onion (*Allium cepa* var. Cepa L. family Alliaceae) is the second most valuable vegetable crop grown throughout the world. It is rightly called the “queen of the kitchen” [165] and cultivated in several regions of the world. It is used as an indispensable vegetable crop, mostly as a condiment in various cuisines. Onion is consumed universally in small quantities or several times daily in some homes, primarily as a seasoning for flavouring of dishes, soup, sauces, and sandwiches. The immature or mature mildly flavoured and colourful onion bulbs and green leaves are also eaten as salad or cooked as a vegetable. Sometimes, it is processed by dehydration and used as onion flakes and powder. It is known for its unique pungent flavour and its alliaceous odour. A volatile compound known as allyl-propyl disulphide is mainly responsible for its distinct pungency. Onion is often used as a part of traditional medicines, and has been shown to be effective in preventing heart diseases and other diseases [17]. Its medicinal and therapeutic effects include antiplatelet aggregation, blood sugar lowering, and fibrinolytic effects. The bulb juice is generally used as a smelling agent during faintness and hysterical convulsions. Flavonoids like quercetin are present in good amount in onion [72]. This, along with sulphur compounds such as allyl propyl disulphide, is beneficial to human health [68] and is believed to be cancer preventive [91].

Watt and Merrill [203] reported 11 amino acids in onion. Although the nutritive value of onion may differs with respect to varieties, in general, 100 g of raw onion bulb contains about 9 mg of ascorbic acid, 501 μg vitamin A, 0.04 mg of riboflavin, 0.03 mg of thiamine, 0.02 mg of niacin, and the rest is the carbohydrates that constitute the dry matter of the bulb. Augusti [17] reported that 100g onion comprises of about 86.8 g moisture, 1.2 g protein, 0.4 g minerals, 180 mg calcium, 0.7 mg iron, and 50 mg phosphorus. Although the average nutritional value of onion is low (2.06), it is mainly used because for flavoring and seasoning of food.

Presently, in the world, 4.9 million hectare of area is under onion cultivation, which produces 93.16 million tons of onion with an average productivity of 18.8 tons/hectare [55]. In India, onion is cultivated in 1.32 million hectares, which result in production of 20.9 million tones. The average productivity is of 15.86 tons/hectare [161]. India holds first position in the total area, second in production after China. India ranks third in export after Netherlands and Spain and exports onion to Gulf Countries, Bangladesh, Malaysia, Singapore, Sri Lanka, Nepal and Pakistan. Maharashtra, Gujarat, Karnataka, Orissa, Uttar Pradesh, and Andhra Pradesh are main onion producing states of India [191].

Considering the importance and production of this crop, greater attention is needed for development of improved varieties with desirable quality traits, suitable for particular geographical production areas. In the U.S.A and Japan, F1 hybrids occupy large cultivable areas, while in European and Asiatic countries like Holland, U.K., India, and many others the open pollinated varieties are more preferred over F1 hybrids [49]. This investigation involves characterization and evaluation of various genotypes of onion for optimum production and qualitative traits suitable for Ladakh a high altitude, cold desert Trans-Himalyan region in India.

1.1 Taxonomy and Botany

Common bulb onion belongs to the class *Monocotyloneae,* superorder *Liliiflorae*, order *Asparagales,* family *Alliaceae*, genus *Allium*, species *cepa* and variety *cepa*. The green, tubular leaves, shallow fibrous roots, and a bulb makes up an onion plant. The erect stem can reach to a height of 100–200 cm. Modern varieties of onion grow to a height of approximately 15–45 cm. An umbel-like inflorescence comprised of white or greenish-white small flowers grows at the tip of the stem. The fruits are capsules containing black flat seeds. The edible bulb can grow up to 10 cm in diameter with several overlapping layers on a central core. The green leaves of the plant are the extensions of the outer food-storage leaves. Onion bulbs may be flat, globular or oblong in shape, and may vary from white, brown, yellow, to red in colour. The bulb is composed of fleshy and enlarged leaf bases. The outer leaf bases become scaly upon loosing moisture and inner leaves become thick and fleshy as the bulb develops.

The genus *Allium* is broadly distributed over temperate to subtropical zones in the northern hemisphere. Present day Turkey and Afghanistan mark the primary center of diversity for the genus, being the origin for nearly 200 of the 500 *Allium* species that have been documented. An additional center of diversity is situated in western North America, where high foci of species are confined to mountainous areas [73].

Like most *Allium*, onion is diploid with chromosome number sixteen. Despite having relatively few chromosomes, bulb onion has an enormous genome when compared to other angiosperms. The genome of bulb onion has about 15,290 megabase pairs of DNA per chromosome, making it approximately 107 times the size of *Arabidopsis thaliana* [14], [75]. Onion leaves are hollow with longitudinal symmetry. Leaves are arranged in a distichous phyllotaxy, as new leaf blades emerge 180^o from the earlier leaf [47]. Onion leaves can be divided into two morphologically different parts: 1) the 5-leaf base that forms a sheath through which the next leaf will arise, and 2) the leaf blade that is hollow, but closed at the tip and flattened on the adaxial surface [47]. Each succeeding leaf increases in size, until bulbing is initiated.

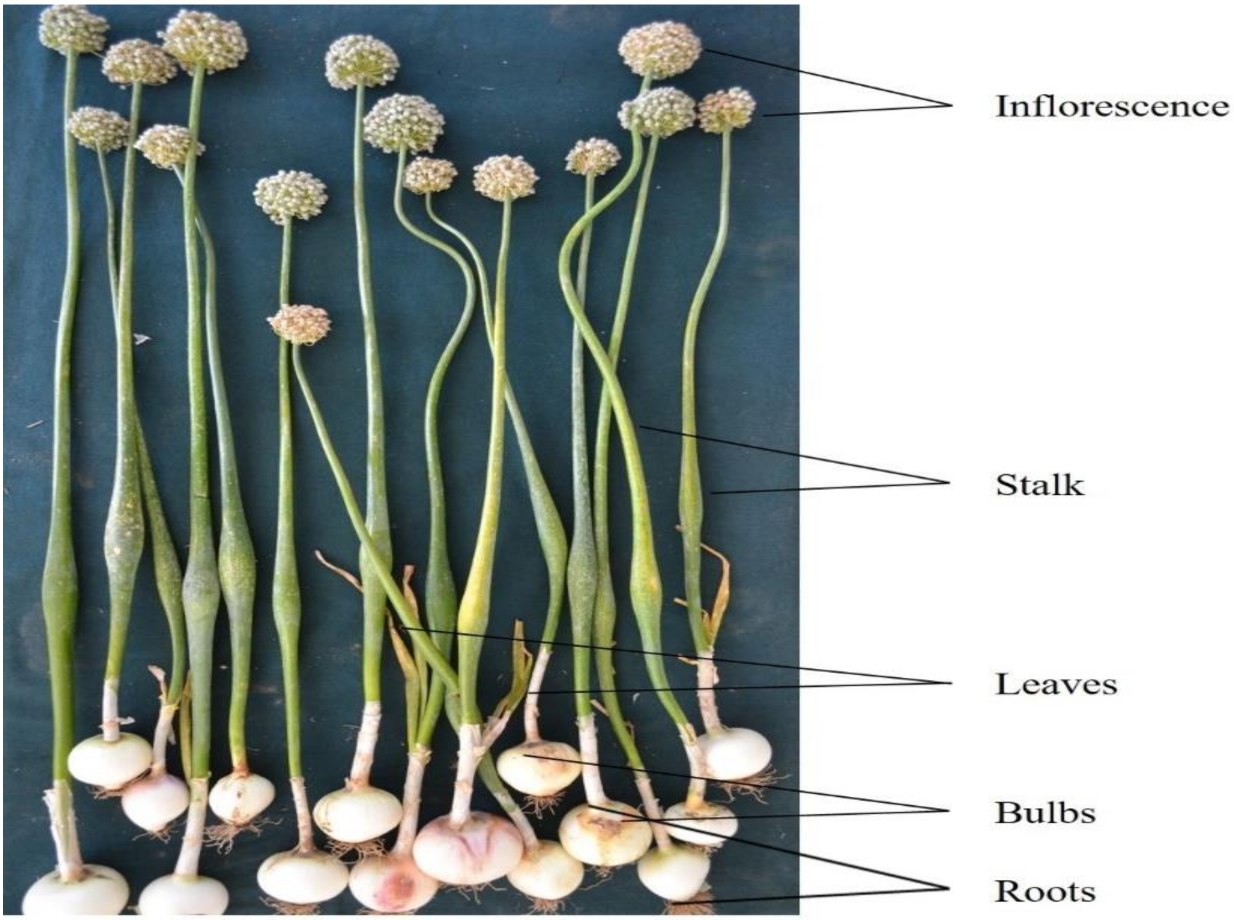

Figure 1.1: Different parts of onion (*Allium cepa* L.) plants.

During bulbing, newly formed leaves remain smaller until no new leaf blades are formed at all [149]. The leaf bases form a stem-like structure that is called the *pseudostem* in order to distinguish it from the true stem at the base of the plant [132].The vegetative axis of the onion consists of a flattened stem, from which leaves rise in a rosette pattern. At germination, a primary root arises from the onion seed and is comparatively short-lived. Subsequent adventitious roots are produced continuously from the stem [47]. Roots typically do not branch, and have few, if any, root hairs. Additionally, onion roots are shallow, often growing no more than 50 cm below the soil surface [140].

Onions are biennial, and must commonly undergo vernalization just before flowering in their second season of growth [143]. Temperature is the primary factor affecting inflorescence development. Generally, bulbs must be exposed to temperatures of 5-10 °C for a period of one to two months in order for vernalization to occur. Plants produce a seed stalk and an inflorescence in a process called bolting [149] if plants are exposed to cool temperature for adequate duration during their first season of growth.

Bolting can be reversed if onions are suddenly exposed to higher temperatures. If this occurs, the seed stalk return to vegetative growth and bulbing will continue [143].

The last leaf formed is called spathe, which is not a true leaf, encloses the floral apex [47]. The seed stalk, or scape, is a single elongated internodal segment that separates that last true foliage leaf and the spathe. Elongation occurs at the base of the scape through a single intercalary meristem [47]. When the scape reaches a height of one to two meters, the spathe splits, revealing the inflorescence. The onion's inflorescence is an umbel, and may contain 50 to 2000 flowers [47]. Generally, flowers near the top of the umbel open first, with all flowers opening over a period of two to four weeks [143]. Individual flowers are protandrous and shed most of their pollen in two to three days. As anthers dehisce, the style elongates, reaching its final length after complete dehiscence [143]. Individual flowers generally contain five whorls, consisting of three different organs each [47]. The two outermost whorls each contain three perianths, while the next two whorls each comprise three stamens. The innermost whorl contains three carpels arranged to form a syncarpous gynoecium, with each carpel having one locule, inside which are two ovules [47], [54].

Onion is an out crossing species, and is typically pollinated by bees or flies in commercial fields [141]. Seed are collected and harvested when about 25-30% of the umbels show ripe seed. The whole umbel is harvested together with a portion of the scape, which is then dried using forced air [141].

The most important part of interest of the onion plant is the bulb, which is an aggregate of swollen leaf bases and the vegetative stem axis. The bulb is made up of a sequence of scales, which are the bases of a few outer leaves that have lost their blades. Inner scales are leaf bases that have never formed leaf blades, and a few sprout leaves in the center that may form leaves in favourable conditions [47]. Outer scales are protected by a thick cuticle, which avoids desiccation. When bulbing is induced, photosynthate that was formed in the leaf blades is translocated to the leaf bases. This causes swelling at the base, and the development of a bulb [149]. Generally, the innermost (youngest) scales act as a robust "sink" for photosynthate than the outermost (oldest) scales during active bulbing

[80]. Bulbs come in a variety of shapes viz., flattened disciform, globular, ovoid, bottle-like and pear-shaped [73].

1.2 Onion as an agricultural crop in Ladakh

The region of Leh-Ladakh, is a high altitude cold arid zone of India, which is situated in the high mountains of the north-western Himalayas in Jammu and Kashmir, India. Leh-Ladakh makes 87.4 percent of total cold arid zone of India and geographically located between 32°15′ to 36° north latitude and 75°15′ to 80°15′ east longitude [178]. It is located at an elevation of 2550–8000 m from mean sea level along the valley of the Indus river.

The civilian population and deployed armed forces in Leh-Ladakh are heavily dependent on supply of onion from rest of country. This outside supply often falls short as result of difficulties in transportation due to geographical and climatic conditions. Road transportation remains closed during winters as a result of heavy snow fall at high altitude passes. The indigenous production of onion which could complement the shortage is almost negligible due to lack of appropriate varieties which perform well in extreme climatic conditions and limited growing season prevailing in the region.

1.3 Climatic conditions of Ladakh

The climate of Ladakh is most unusual, extreme, and unique in the world. The characteristic features that define the climatic conditions of Ladakh are intense sunlight, elevated evaporation rate, high wind speed, diurnal pattern of temperature fluctuations, and abridged growing season. The area receives insignificant precipitation during growing season. The region witnesses almost no rain amidst snowy mountains. The region is beyond the reach of the monsoons that affect most of India because the Himalayas block nearly all the rains from the south, creating a desert in the rain shadow. Most of areas receive only about 100 mm average rainfall in a year. Owing to the high altitude and high wind speeds from central Asia the winters in the region are long and bitterly cold, whereas summers are mild. Approximately 300 days of the year are sunny in this region that receives abundance of sunshine and even the month of December receives minimum radiation as 4.32 kWh per day [201].The soils of Ladakh are poor in fertility mainly with low water holding capacity. The soils varies from gravely, sandy, sandy loam, silty, clay loam to clayey with pH ranging from 7.4 to 9.6. Salinity is a problem in certain areas [201].

1.4 Onion Production in Ladakh: challenges and solutions

Considering the scope of crop production, the whole arable land of Ladakh has been brought under agricultural management by local people and has been zonalised as upper, central, and lower, based on the altitude variation. All cultivable zones of Ladakh are good for vegetable production. Despite the incredible restrictions during eight-month long winters, short growing season and virtually no effective rain, Ladakhis traditionally produce many agricultural commodities more than their needs. Onion is an important part of the vegetable cultivation in the region. Onion can be grown through direct sowing of seeds in the field, but requires longer time (about 8 months) for the crop to mature. This method is labor-intensive, requires thinning, more number of weeding, hoeing, and irrigation for successful crop production, and such a long period is not available in Ladakh. Therefore, to reduce the cropping period, the crop is grown by transplanting seedlings grown under protected condition or in open field conditions. For transplantation, the seedlings are raised in nursery and about eight week old seedlings are transplanted in the field, which reduces the cropping period by two months. In Ladakh conditions, the seedlings are raised from mid-March to mid-May in protected conditions, and transplanted in the open field in the month of May. After transplantation, seedlings take approximately 10–15 days to come out from transplanting shock for proper establishment. During this period, on an average, 40% seedlings die, and mortality has also been observed for another 10% plants during the cropping period. The remaining established plants show slow growth, which may be due to a small root system and adverse climatic conditions. In the physiographic conditions of Ladakh, crops do not reach the full maturity stage owing to slow growth. Short agricultural season and the onset of winter by October, which results in a low yield with poor quality and cropping intensity remains 100% (single crop in a year) only.

In India lot of research work is carried out on different aspects of onion, there is negligible literature found on onion in the context of the physiographic conditions prevailing in Ladakh. Due to the lack of information on its various aspects, the productivity of onion is low in the region. Based on the estimation, local farmers are able to produce only about 1200 MT onion per annum, which is about 35% of local requirement, leading to a 65 % gap between local production and requirement. Hence, a major part of the requirement of this region is met by importing onion from the other parts of our country. This onion is transported by road during summer months and by air during winter months (especially for armed forces). To fulfil the local onion requirement of the civilian population and armed forces deployed in the region, there is the need to boost production, and regulate the supply through the proper storage of onion.

To raise the productivity of a particular crop in a specific region, location-based specific crop varieties / genotypes and production techniques have to be developed and put into practice. Most of the onion varieties recommended for Northern plains of India do not perform well in Ladakh. Owing to the lack of knowledge, local farmers are growing short day cultivars. The cultivars of this group give low yield with poor quality bulbs in long day conditions of this region. The bulbs of these varieties split during their formation and usually bifurcate easily into 2–5 parts after the harvest. After separation, the bulb remains small in size and poor in shape. In the context of the army’s demand, these types of bulbs do not fit the specifications laid down by the army. Hence, maximum produce is rejected, and the local supply of onion to the army remains low. The farmers get low yield with poor quality bulbs that fetch them low prices in the market. These bulbs have thick neck sizes and do not mature well in the short cropping period of this region. Consequently, the bulbs show poor storage quality and accordingly 20–40% has been observed rotten during winters by following traditional methods of storage. No efforts have been done so far to evaluate onion germplasm in Ladakh region with intent to recommend a suitable cultivar. This investigation is an effort to fill this research gap, in which 25 genotypes collected from hilly regions, procured from NBPGR New Delhi and 9 long day or day neutral plants procured from Bejo Sheetal Seeds Maharashtra were evaluated for various quantitative and qualitative traits at DIHAR DRDO Leh in two separate experiments. The genetic diversity of these genotypes and correlation among different economic traits were also worked out which would be helpful to breeders in planning any region specific onion breeding program in future.

Since the physiographic conditions of Ladakh are different from elsewhere, the production techniques practiced in other parts of the country are not applicable in this region. One of the major challenges here was short crop growing season and onset of winters before crop maturity. It was envisaged that this constraint can be overcome to some extent by somehow reducing the crop duration by adopting a suitable production technology. To achieve this we tested and compared ‘seedling’ and ‘sets’ as onion planting material in Ladakh region. Sets are tiny bulbs of onion, obtained when seedlings are allowed to grow for 90–100 days and bulbs attain diameter of about 1–2 cm. The literature on onion indicates that plants raised via sets as planting material, require shorter growing season. But, no study have been done in Ladakh to validate the hypothesis that set as planting material of onion could be one of the solution to the problem of shorter growing season.

Other aspect of the research work involves characterization of onion genotypes for mineral content and post-harvest storage quality of the bulbs. Researchers are now a days are interested to improve the nutritional quality crops. Onion is consumed by all sections of people throughout the year, so could be good means of fighting elemental deficiencies especially in Ladakh region where availability and consumption of other vegetables is already scarce. Therefore it is prudent to identify germplasms with high levels of the mineral nutrients for direct recommendation of high mineral genotypes inclusion pf such genotypes in future breeding programs

Poor self-life and inadequate storage facilities results in huge losses of onion produce in India. In Ladakh region such losses further jeopardize the availability of onion. It has been suggested that the storage life of onion is greatly affected by cultivar, storage regime, and temperature. This means storage and requirements and conditions at Ladakh region would be entirely different from that the rest of places, as here the produce need to be stored during extremely cold freezing winters (which cause freezing injuries) to mild summers. So it is important to characterize genotypes for their storage potential in the prevailing climatic conditions.

So a multidimensional research approach has been implemented to overcome the constraints of low productivity and availability of onion to armed forces and local populace in the region. Under this approach, evaluation, characterization, and selection of high-yielding varieties, and validation of hypothesis of reducing crop duration using ‘sets’ as planting material, and characterization of onion genotypes for mineral content and postharvest keeping quality were under taken, The study was conducted to achieve following specific objectives.

1. Morphological variations and relationship among onion germplasms for quantitative and qualitative traits in the trans-Himalayan Ladakh region of India.
2. Comparative performance of onion genotypes using ‘Sets and Seedlings’ as planting material at Leh cold desert.
3. To determine the mineral content of bulbs of different long-day onion genotypes grown in the agro-climatic conditions of Ladakh.
4. Evaluation of onion genotypes for post-harvest keeping quality of the bulb in agro-climatic= conditions of Ladakh.

CHAPTER 2

REVIEW OF LITERATURE

2.1 Factors affecting onion bulbing

Bulb formation depends primarily on photoperiodic response, but also influenced by other environmental factors viz. light intensity, light quality, temperature, nitrogen nutrition, and irrigation regime. Unlike several documented photoperiodic responses in plants, bulb formation in onions requires a continuous exposure to a critical day-length. Bulb formation is reversed, if plants are exposed to a non-inductive photoperiod for a certain period after bulb formation has started [30]. Onion varieties can be classified into short-day, intermediate-day, or long day, based on the photoperiod length that the plants must be exposed with the intention of initiating bulbing. Short-day plants form bulb when exposed to 11-12 hour photoperiod, whereas long-day cultivars need14-16 hours day lengths to form bulb. Intermediate-day plants need day length near 13 hours to form bulb [30].

Light intensity also plays a role in bulbing. It has been reported that bulb scales are initiated earlier with increasing light intensity [30]. Besides light intensity, spectral quality also plays a role in onion bulb development. Lower ratio of red light (660 nm) to far-red light (730 nm) light enhances bulbing. In addition, bulbing has been reported to be delayed or even reversed, when plants are exposed to periods of red light during an inductive photoperiod [128]. Temperature is additional factor that affects the rate of bulbing in onion. Plants grown at temperatures below 10 °C tend to have unpredictable bulbing, even when exposed to inductive photoperiods [32]. The bulbing rate generally increases with temperature; however, bulb yields tend to decrease at temperatures approaching 30 °C [33], [183]

Agronomic practices, such as nitrogen fertility also affect bulb development in onion. According to Brewster and Butler [29] nitrogen applications in the late growing season may delay onion bulbing. Additionally, experiential observations have revealed that high levels of nitrogen late in the season may increase the rate of bulb splitting.

When bulbs close to maturity, the leaf sheaths (pseudostem) weaken because of leaf senescence, predicated by the loss of photosynthate from the leaves during bulbing [79]. In due course, the pseudo stem can no longer support the mass of the leaf blades, and the foliage falls. When the foliage of an onion lodges at maturity, the plants are said to go "tops down."

Generally, harvesting of onions is carried out in commercial production when almost 50% of the plants in a field have gone tops down [139]. During harvest, onion bulbs are pulled out and left in the field to cure under direct sunlight or in containers to be cured using forced air [139].

2.2 Evaluation of onion germplasms for quantitative and qualitative traits variation

Variability in germplasm is a prerequisite for effectiveness of selection in plant breeding. The progress due to selection in quantitative characters depends primarily on magnitude and nature of genetic variations present in the population to be improved. Variability within a population is of two types, (i) variability due to genotype or heredity, and (ii) variability due to environment. Genotypic variance is due to the different genotypic constitution of the individuals in a population. Variability due to the environment or environmental variance, which by definition embraces all variations of non-genetic origin, can have a great variety of cause, its nature depends very much on the character, and the organism studied. Variability is the distinctive feature of living beings and forms the foundation of plant improvement. Thus, variation, as a matter of fact, offers a working bench for selection in crop improvement program.

Singh et al. [174] concluded that various economic plant traits of onion are polygenic in nature and highly influenced by the environment. It is important to have information about nature of association of bulb yield with yield contributing characters in order to improve the productivity through selection of better varieties. Pakyurek et al. [136] evaluated different varieties of onion for yield and quality traits and concluded that all varieties do not gave the similar response. They observed that Mercato was high yielder and lower yield was obtained in case of Summit Fl. Cultivars Renate, Ailsa Iraig, and S.S.I. were studied [58] and It was found that yield of these cultivars were 30.00, 31.06, and 29.31 tons / ha, respectively.

Kandil et al. [82] reported high diversity for quantitative and qualitative traits in the studied genotypes. Giza 20 and Composite 9 were found to have the highest bulb weight followed by Giza Red. Whereas dry matter and TSS content was found highest in Giza White followed by Giza 20. Shah et al. [166] recorded that a local cultivar Parachinar was best in terms of number of leaves (15.4), leaf length (47.7 cm), neck height (6.5 cm), plant height (77.9 cm), and total yield (33.1 t/ha) among all the studied genotypes.

Soleymani and Shahrajabian [182] found that different cultivars significantly varied with respect to fresh weight of foliage, plant height, bulbing ratio, total yield, weight of bulb, yield, dry matter, and nitrate content in bulb. This indicated that physico-chemical characters of onions of different genotypes depend on the genetic constituents of the cultivar. They reported that the Cisakht cultivar among all the other studied cultivars contained maximum values of these traits.

Ahmed et al. [4] reported highest bulbing ratio 90 and 120 days after transplanting in case of cultivar Giza 20 showed. The cultivar Giza Red was found to have the highest plant height, number of leaves/plant, and foliage fresh weight per plant at 90 and 120 days after transplanting. Dry matter and TSS in bulbs after harvesting and each month after harvesting during storage period were found highest in the cultivar Giza Red in both seasons.

Singh et al. [175] in a study on bulb diameters found highest bulb diameter), bulb size index and weight of 20 bulbs in advance line ‘652’. The gross yield (41.4 tons / ha) and marketable yield (34.8 tons / ha) were also recorded highest in advance line ‘652’, which were at par with ‘672’ (38.8 tons / ha and 34.8 tons / h, respectively).

2.3 Comparative performance of onion genotypes using ‘Sets and Seedlings’ as planting material

Sets are baby bulbs weighing 2 to 3 g. Plant raised via sets are adapted to short growing season and less affected by stressful environments. Sets can be used to raise crops in less time and more healthy plants than either seeds or seedlings [164]. O’connor [133] observed sets as one of convenient and safest planting material for onion production both at the small scale and at commercial level. This is because the emerging plants are strong, vigorous and easily establish under a stressed environment. The crop raised through sets usually catches early market and fetch good price. Colby et al. [41] stated that the size of sets is closely related with the bulb yield. Total yield from plants was a significantly higher compared to methods in which seedling were transplanted and direct seeding. Onions planted through sets gave double the yield of those planted directly through seeds. Kepkova et al. [89], Ketema et al. [90] reported that onions planted through sets gave a significant higher total yield than transplanted onions. He also found that the planting methods and cultivars significantly affect time of bulb maturation. Bulbs matured significantly early in set planting i.e 19 and 44 days earlier than transplanted and direct sown onions, respectively. Vik [193] reported that onions grown through direct sowing showed 13 days delayed maturity as compared to onions grown through the transplanting method. Early maturity is one of the advantages of the transplanting over direct sowing method [113]. Madisa [105] examined the relationship between size of set and bulb yield. The highest bulb yield (45.40 tons / ha) was observed when medium-sized sets (18-25 mm diameter) were used compared with large sized sets (37.6 tons / ha) and small sized sets (30.6 tons / ha). The sizes of large and small sets ranged between 20–30 mm and 12–18 mm in diameter. Khokhar et al. [93] also reported that medium-sized sets (16–20 mm diameter) of onion produced the highest bulb yield (43.8 tons / ha). Schiavi et al. [162] reported that Yellow Vaquero cv. had the highest yield (43 tons / ha), and showed the most consistent quality among all cultivars that were investigated through sets.

2.4 Variation in mineral content of onion bulb

Ali et al. [8] observed significant variation among considered varieties with respect to calcium, phosphorus, sodium, potassium and magnesium. Cultivar ‘MA’ showed the highest potassium and phosphorus, cultivar ‘BHP’ had the highest calcium content, cultivar Z6 had the highest sodium content and cultivar ‘RA’ showed the maximum magnesium content.

Cota et al. [43] studied the mineral content of new varieties of onion from Bosnia and Herzegovina and found that mean values for some minerals were low in these varieties. Dan Zaria (Red skinned onion) showed the highest content of minerals. Akinwande and Olatunde [6] measured that trace elements, iron, aluminium, zinc, copper, manganese and nickel had the range of values of 30.16-160.69 mg/Kg, 23.30-41.46 mg/Kg, 26.87-66.08 mg/Kg, 24.73-28.83 mg/Kg, 11.53-17.39 mg/Kg, and 4.38-5.11 mg/Kg, respectively. Iron content was highest in Dan Zaria (brown skinned) when compared with the other samples. Yahay et al. [206] evaluated the nutritional composition of onion bulbs and stalks. The study indicated that bulbs are a better source of nutrition, onion bulb, stalks both are good sources of fiber, minerals, and vitamins A, and C. Chope and Terry [40] conducted an experiment to find out the difference in mineral composition when the diverse cultivars are grown in the same soil and environmental conditions. The study showed a significant difference in the mineral composition of the bulbs of different cultivars grown at the same location. It was also possible to separate three cultivars studied, on the basis of mineral content.

2.5 Post-harvest keeping quality of the onion bulbs

Storing onion bulbs effectively is essential for the onion industry for two reasons: 1) it facilitates onion availability throughout the year, and 2) onions are a biennial crop, and therefore, bulbs for seed production should be stored until the following growing season. Bulbs are storage organs by nature, and therefore, are well suited for storage. Onion dormancy starts with a decline in respiration [114]. Typically long–day and high-dry-matter-type cultivars showed better shelf life than short-day low-dry-matter types [69], [185].

Short-day type of onions is adapted to lower altitudes and they naturally do not have to contend with long overwintering periods. Hence, they have a tendency to have short periods of dormancy and frequently break down dormancy quickly if stored at higher temperatures [121]. To reduce sprouting in storage, farmers harvest onions for storage later than fresh market bulbs, store onions in cool temperatures (0-4ºC), and use maleic hydrazide, a sprouting inhibitor [31], [42], [155], [179], [199]. Loss of water through the neck of the onion bulbs is also a major factor affecting onion storage [145]. This is lessened using controlled-atmosphere storage at 5% O_2, 75% relative humidity [179], [180], [181]. All the above stated storage methods are employed to reduce respiration in bulbs, and thereby reduce dry matter losses in storage [75], [102],[155].

Bajaj et al. [20] showed that the varieties of onion bulbs that contain high dry matter, TSS, phenolic compounds and non-reducing sugar could be stored for longer time. Chang [37] found that there is a direct relation of physico-chemical composition of bulbs, mainly dry matter, TSS, non-reducing, and reducing sugars content, with the storage life of onion bulbs. The onion bulbs containing higher levels of dry matter and pyruvic acid had good storage life and quality. Darbyshire and Henry [45] studied nine cultivars of onion and found that with the increase in dry weight percentage, the fructose content also increased in the bulb during storage. Rutherford [151] stated that in temperate regions, the change in the carbohydrate constituent is the most important biochemical change that occurs in the stored onion bulbs. Chang [37] found that onion bulbs with low reducing sugar content have better storage quality. Magdum [106] carried out an experiment in which it was shown that the cultivars with high non-reducing sugar also contained high levels of total soluble solids and dry matter but lower reducing sugar content. Patil [138] stated that the dry matter, total soluble solute, and non-reducing sugar showed increasing trends, whereas reducing sugars and proteins decreased during six months storage period. The mean dry matter percentage in onion bulbs was reported as 13.4 % [66] and 11.3 % [151]. The bulbs of red onion were found to have increased sprouting and decreasing T.S.S content when stored at room temperature [172]. According to Nettles and Smith [131] onions with their tops have more dry matter content than those that have removed tops at the time of harvesting. Onion varieties with higher dry matter content are less prone to storage and sprouting loss [158]. Patil and Kale [137] studied the storage quality of different varieties of bulb and observed that the varieties having higher dry matter contents and total solid solute had better storage life. Onion bulbs with high TSS, high dry matter, non-reducing sugar, thin necks, and medium size showed good storage quality. Shaha et al. [166] stated that the medium size onion bulbs with higher amount of TSS, non-reducing sugar, and thin necks, can be stored for longer time.

Satodiya and Singh [160] found that non-reducing sugar, amount of reducing sugar decreased at the end of a 150-day storage period. Whereas total soluble solids, non-reducing sugar, and total sugar content increased after 150 days of storage of onion bulbs. In their study, Croci et al. [44] found that the carbohydrate content in the onion bulb varieties they studied remained constant during 180 days of storage of the bulbs. Further, there was no significant influence of storage on the ascorbic acid content. They also studied effect of storage method on storage quality of onions and found that the onion bulb stored in a two-tier storage structure had better physico-chemical constituents than those stored using conventional storage methods.

Agic et al. [2] observed that the onion bulbs having higher dry matter content and larger number of dry scales are better for longer storage periods. It was reported that dry matter content increased from 11.4 to 12.3% and total soluble solids increased from 10.6 to 11.9% during the storage period, although the reducing sugar percentage reduced from 3.47 to 2.35%. Enhancement in non-reducing sugar content (from 5.26 to 6.61%) in onion bulbs was reported during six months of storage Patil and Kale [137]. Hanson [73] observed that different varieties of onion bulbs contained varied amounts of dry matter, which affected the length of the storage period of the onion. Pramanick et al. [141] found that variety SI-126 contained highest TSS, dry matter content, and ascorbic acid, which increased in storage period.

Even though sprouting and water loss represent accountable difficulties for storing short day onions, disease accounts for most postharvest losses [96], [144],[188]. The principal disease in onion storage is neck rot, caused by the fungus, *Botrytis allii*. The storage losses in some years due to neck rot can reach 35% of stored product [203].

2.5.1 Botrytis *allii*

Botrytis allii can infect bulbs in many ways. Seeds are the primary source of infection in European countries, and are occasionally a source of infection in the U.S. [52], [118], [115], [196]. Additional potential sources of *B. allii* infection include sclerotia and mycelia in infested onion debris and overwintering crops [117], [198]. Mycelia, growing on or under the seed coat, penetrate the tip of the developing cotyledon during germination and infect developing seedling. Conidiophores growing on necrotic tissues release their conidia and consequently infect other leaves [118]. Infected leaves senescence due to fungal infection.

The crop can then sustain the infection during the growing season, sometimes without displaying additional symptoms, signifying that the fungus may be capable of biotrophic growth [118]. As leaves senesce before harvest, the infection becomes active, spreading rapidly on necrotized leaves. During harvest, mycelia from germinating conidia infect bulbs through open wounds in the neck area when the foliage is cut and removed [24], [116]. Studies suggest that the fungus does not attack dry bulb or outer neck tissues [116], [197]. It is expected then that Botrytis neck rot does not spread through bulb-to-bulb contact in storage (when outer scales are dry). Instead, the appearance of *B. allii*in storage is more likely due to the increasing deterioration of bulbs previously infected from the field [114], [118], [115].

2.5.2 Other onion storage pathogens

Some more fungal diseases and many bacterial pathogens have been shown to cause accountable field and storage losses to onion produce [110]. Sour Skin, *Burkholderia cepacia,* (formerly *Pseudomonas cepacia*) is a gram-negative aerobe that can enter the onion through the leaf axils, resulting in bacterial lesions on the leaves [110]. The disease can then advance to the bulbs leading to water-soaked and macerated scales, producing typical sour skin symptoms. *Burkholderia cepacia* often infects the plant through a wound, generally at young leaf stage [85], [95]. When the pathogen enters the plant, it extends through the intercellular spaces releasing pectolytic enzymes, which develop a soft rot and maintain a water-clogged environment needed for *B. cepacia*to survive [149]. Kawamoto and Lorbeer [86] suggested that *B. cepacia* could extend all over intercellular spaces, and reported that the infection in numerous scales may result from a single infection spot. For the degradation of polysaccharides in the intercellular space and middle lamella pectolytic enzymes (polygalacturonases) are necessary, enabling *B. cepacia*to spread [65], [68]. Increased Ca^{2+} has been reported to reduce fungal polygalacturonase activity and make stronger the middle lamella [34], [101], [194]. A similar trend may occur with bacterial disease suppression and polygalacturonase inhibition. One more economically important onion bacterial disease is centeral rot caused by *Pantoea ananatis* that is a gram-negative bacterium. Central rot can cause yield losses of up to 100% [63], [119]. First symptom of centeral rot appear on the center leaves of the plant and looks like a water-soaked spots ultimately taking on a bleached appearance as the disease progresses [110]. Inner bulb scales become watery and attempts to lift bulbs by pulling on the foliage by which outer scales separating from the bulb. The disease was first assumed to be introduced through infected seed; however, additional evidence found that the bacterium was endemic and colonized a number of asymptomatic weed species in the onion growing regions [62],[195].*Pantoea ananatis* may transfer from weed species to neighboring onions through tobacco thrips (*Frankliniella fusca*), a commonly found insect pest in onion fields [64]. *Pantoea ananatis* was first observed in onion in the USA in 1997 and little is known about the mechanisms of action of this bacterium once inside the plant [63]. Strains of *P. ananatis*utilize cellobiose, sucrose, glycerol, and inositol, but not pectins or gelatins as carbon sources *in vitro* [27].

Another fungal disease in onion that can cause significant lossesispurple blotch the causal agent *Alternariaporri*infects leaves via direct penetration of the leaf surface or opening through the stomata. Upon infection, secondary hyphae grow and transfer through intercellular spaces until uninfected mesophyll cells are reached and subsequently penetrated [18]. *A. porri*secretes pectolytic enzymes like *Botrytis spp.*, enabling cell wall penetration.

CHAPTER 3

MORPHOLOGICAL VARIATIONS AND RELATIONSHIP AMONG ONION GERMPLASM

Abstract

In this investigation the genetic variation of twenty-six accessions of onion based on quantitative and qualitative traits and association among different traits were studied at high altitude. The germplasm were found to be rich in variability for all the considered characters. Differences among genotypes with respect to studied traits were statistically significant and hence can be attributed to their genetic complement. This provides breeders opportunity to select suitable genotypes for direct recommendation or selection as parents in future. The genotype IC-0512324 showed highest TSS, dry matter, average bulb weight and bulb yield. All genotypes grouped into four different clusters. Subcluster I and IV were found to most divergent as reflected by inter cluster distance and it is recommended that parents should be chosen from these clusters to exploit heterosis in future breeding programs. Principal component analysis extracted three PC's which contributed 95.61% of variation out of which PC1, PC2 and PC3 contribute 77.52 % , 10.72 % and 7.38 % of variability respectively among 26 accessions. The characters such as average bulb weight, bulb yield, leaf length, total soluble solids and equatorial diameter accounted for major part of the variance.

3.1 Introduction

Onion is one of most indispensable agricultural commodity of Indian Kitchens and that is why it remains in high demand round the year. Rise in onion prices immediately attract public ire and have resulted in fallout of many exiting governments after elections I India. Ladakh is a high altitude cold arid zone of India, which is situated in the high mountains of the northwestern Trans-Himalayas. The local populations of Ladakh and Indian armed forces deployed in huge numbers are heavily dependent on supply of onion from rest of country. This outside supply often falls short as result of difficulties in transportation due to geographical and climatic conditions. Road transportation remains closed during winters as a result of heavy snow fall at high altitude passes. The indigenous production of onion, which could complement the shortage, is almost negligible due to lack of appropriate varieties, which perform well in extreme climatic conditions and limited growing season prevailing in the region. One of the major reasons for low local production is non-optimal performance of exiting high yielding varieties in the extreme climatic conditions of Ladakh. Onion is a winter season crop when days are short in most of growing areas and most of the high yielding onion varieties are short day plants. The crop is grown in summers at high altitude Ladakh, during which days are long. Moreover, the crop growing season in Ladakh is also short. These along with some may be the reason for non-optimal performance of exiting onion varieties at high altitude conditions. The bulbs of these varieties split during their formation, remains small in size and poor in shape. Hence, maximum produce is rejected, and the local supply of onion to the army remains low.

This means that research efforts are required for the evaluation of onion germplasm for production and performance with respect to quantitative and qualitative traits in the prevailing climatic conditions of Ladakh. No such efforts have been done so in Ladakh region with intent to recommend a suitable cultivar. Diversity in plant genetic resources (PGR) offers plant breeders the opportunity to select better performing genotypes and develop novel and better cultivars with desirable characteristics by hybridization of better performing distantly related genotypes.

Improvement in productivity and quality parameters can be accomplished by selecting genotypes with favourable trait combinations from nature or by hybridization.

Genetic variability is an essential pre requisite to do crop improvement for traits like increasing yield, wider adaptation, desirable quality, and pest and disease resistance through selection and breeding. Selection and inclusion of genetically diverse parents in breeding program has enormous importance for successful recombination breeding [15] [7]. The specific information on the nature and degree of genetic diversity helps plant breeders in inclusion of genetic diverse parents in hybridization programs [157]. Genetically diverse parents selected on the basis of the genetic divergence analysis should be more promising as it provides opportunity creates to more recombination of genes. Mohanty and Prusty [125] and Mohanty [126], reported similar results in case of onion.

Knowledge of association among different traits in the base population is also another pre-requisite to initiate and execute selection for yield and other desired traits. Economically important traits of onion are polygenic in nature and are extremely affected by the environment in order It is essential to know of the association of bulb yield with yield-contributing characters in order to improve the yield through selection of genotypes. Principal component analysis (PCA) is a multivariate analysi, which divulge the traits that are decisive in genotype differentiation [99]. It facilitates the easier understanding of and associations among different traits and impact one can have over another.

This investigation is an attempt to assess the degree of genetic diversity with respect to quantitative and qualitative traits including in the bulb yield to directly recommend the out performer for cultivation and figure out the diverse ones for future improvement programs. In this 25 genotypes collected from hilly regions, procured from NBPGR New Delhi and one local cultivar were evaluated for various quantitative and qualitative traits at DIHAR DRDO Leh. These genotypes were included in this investigation as these were collected from hilly regions (though they were not characterized for photoperiodism) and the hypothesis was that at least few of them would be able to perform better then local check. The genetic diversity among these genotypes and correlation among different economic traits were also worked out.

3.2 Materials and Methods

3.2.1 Experimental Site

Ladakh is a high-altitude cold desert having distinct geographical and climatic conditions and is considered one of the most difficult terrains in the world; altogether offering a tough life with a lack of resources. The experiment was conducted from May to October in 2013 and 2014 in the Vegetable Research Unit at the Defense Institute of High Altitude Research, (DIHAR) Leh-Ladakh. The soil at the experimental site is silty loam having pH 7.1±0.2, organic matter content 1.2.±0.4% and organic carbon 4.2±0.5%. The average rainfall in the region is only 102 mm. The mean maximum temperature reaches upto 29.51°C in July and means minimum temperature drops down to -14.98°C in December. The mean relative humidity varies between 33.67 (August) and 51.33 per cent (December).The meteorological data for the period of experimentation obtained from the meteorological observatory of the Indian Airforce Station Leh, are presented in Figure 3.1 and Figure 3.2.

3.2.2 The experimental material

The experimental material consisted of 26 accessions including a local cultivar (Table 3.1) of onion having a broad spectrum of variation, which was obtained from NBPGR New Delhi.

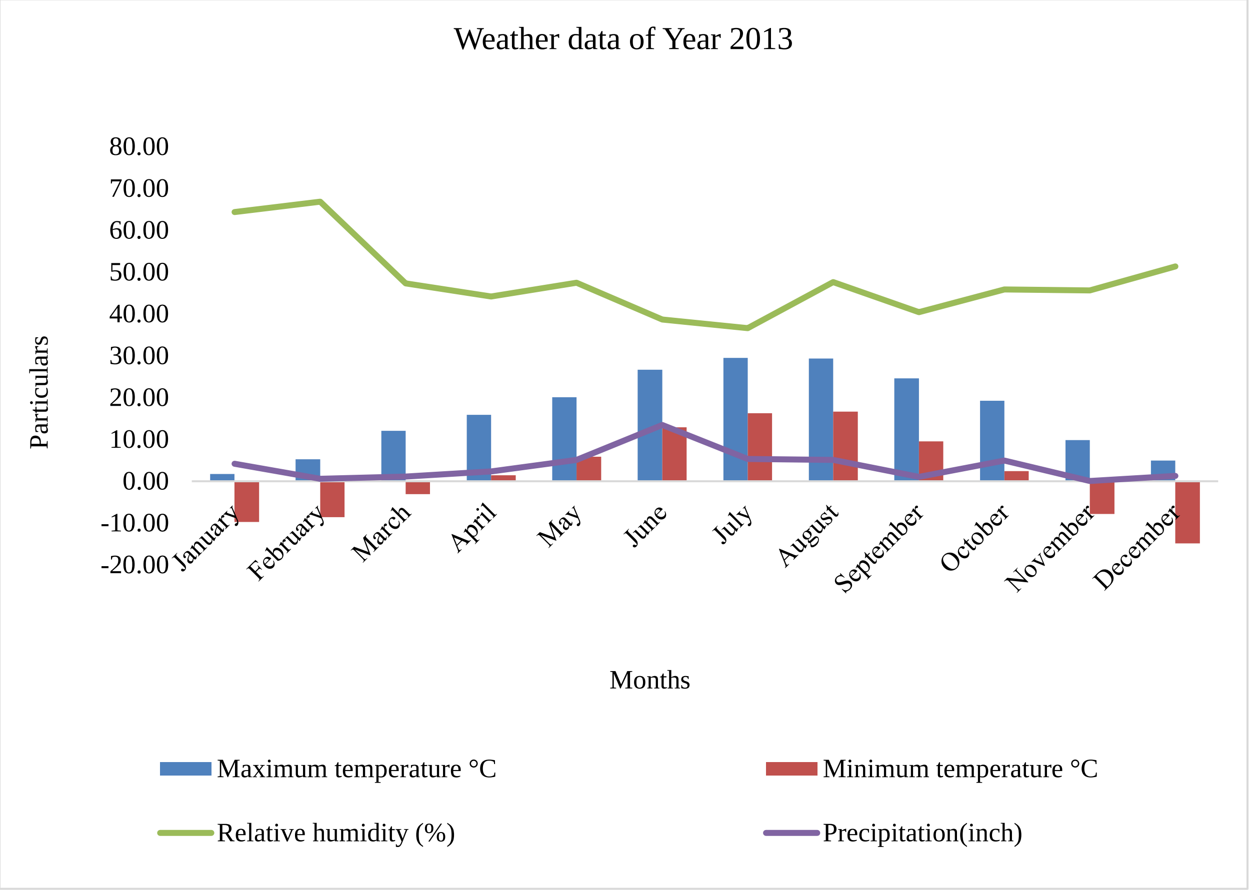

Figure 3.1: Month wise maximum and minimum temperature relative humidity and precipitation recorded during experimentation year 2013

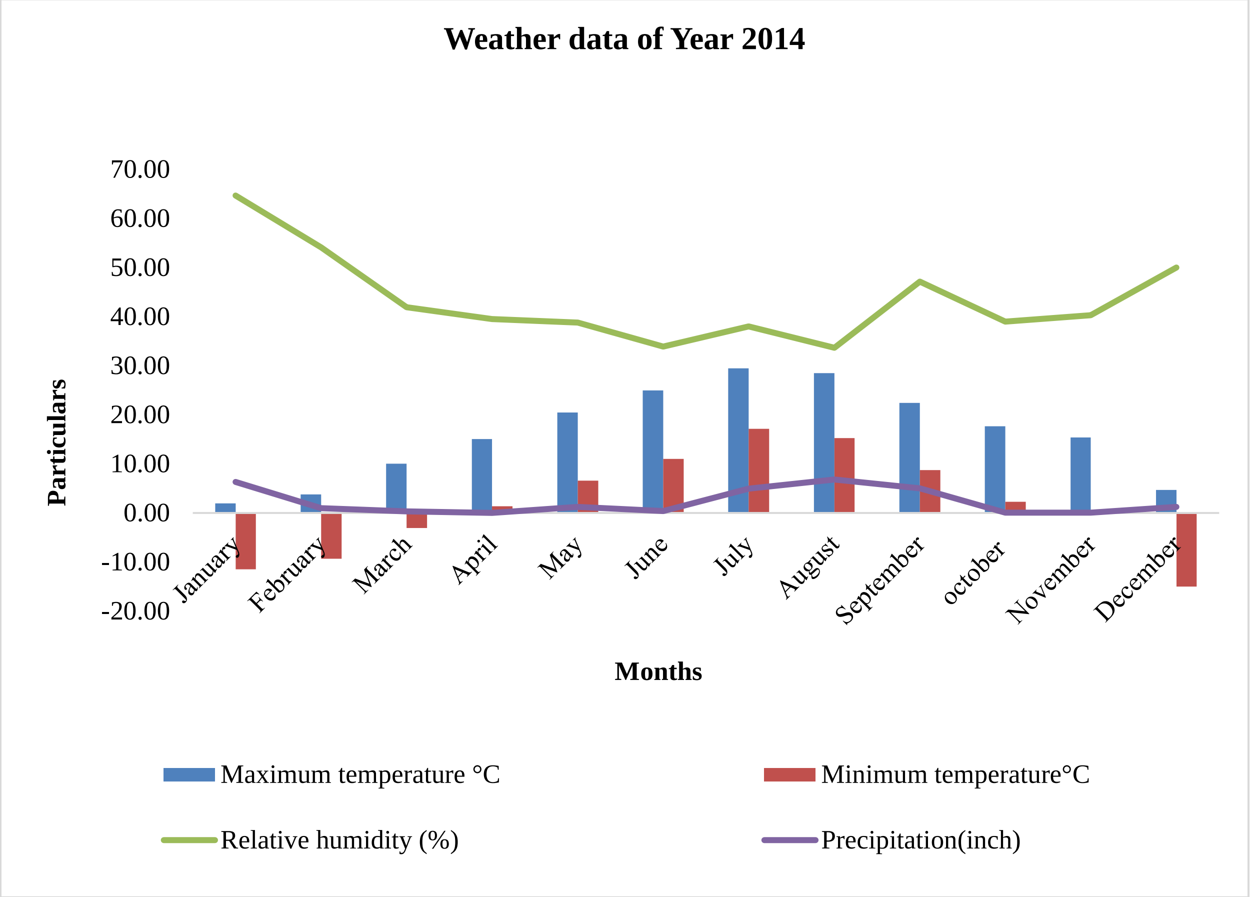

Figure 3.2: Month wise maximum and minimum temperature relative humidity and precipitation recorded during experimentation year 2014.

Table 3.1: List of onion genotypes evaluated at Leh for quantitative and qualitative traits and genetic diversity

S.no.	Genotypes	Source
1	IC-0279582	NBPGR New Dehli
2	IC-0035182	NBPGR New Dehli
3	IC-0035851	NBPGR New Dehli
4	IC-0035856	NBPGR New Dehli
5	IC-0035891	NBPGR New Dehli
6	IC-0035940	NBPGR New Dehli
7	IC-0035992	NBPGR New Dehli
8	IC-0038823	NBPGR New Dehli
9	IC-0047928	NBPGR New Dehli
10	IC-0047940	NBPGR New Dehli
11	IC-0279180	NBPGR New Dehli
12	IC-310990	NBPGR New Dehli
13	IC-0338582	NBPGR New Dehli
14	IC-0356095	NBPGR New Dehli
15	IC-0369521	NBPGR New Dehli
16	IC-0374706	NBPGR New Dehli
17	IC-0374724	NBPGR New Dehli
18	IC-0391544	NBPGR New Dehli
19	IC-0392640	NBPGR New Dehli
20	IC-0392647	NBPGR New Dehli
21	IC-0440229	NBPGR New Dehli
22	IC-0512324	NBPGR New Dehli
23	IC-0524211	NBPGR New Dehli
24	IC-0588677	NBPGR New Dehli
25	IC-0039039	NBPGR New Dehli
26	Local cultivar	Seeds of Local Cultivar were collected from Local Market of Leh-Ladakh.

3.2.3 Experimental procedure and observations

The experiment was conducted in randomized complete block design with five replications and one local check. All the standard agronomic practices and plant protection measures were used. The observations were taken from ten randomly selected plants from each accession in each replication for thirteen quantitative characters viz., Plant Height (CM), Number of leaves per plant, Leaf Length (CM), Leaf width (CM), Neck Thickness(CM), Chlorophyll Content (CCI), Dry Matter (%), Total Soluble Solids

(%), Equatorial Diameter (CM), Polar Diameter (CM), Bulb Shape Index, Bulb Yield (Kg/Plot) and Average Bulb Weight (g) and four qualitative traits viz., Colour of Foliage, Degree of Leaf Waxiness, Uniformity of Bulb Shape, Colour of Bulb Skin. All four qualitative traits were interpreted as per the method of Ekhvaia and Akhalkatsi [52]. The traits were observed as per International Plant Genetic Resources Institute plant descriptors of *Allium species.* Mean values of all observations were calculated for quantitative traits and subjected to analysis carried out by SPSS 21 statistical analysis software.

3.2.3.1 Plant Height (cm)

Plant height was measured from ground level to the tip of the longest leaf when held vertically after 90 days after transplanting. Mean of ten plants from all the blocks was worked out for further computation and it was expressed in centimeters (cm).

3.2.3.2 Number of Leaves

The number of fully grown, green and photosynthetically active leaves were recorded and average number of leaves per plant was worked out from the ten randomly selected plants.

3.2.3.3 Leaf length (cm)

The leaf length was recorded at 90 days after transplanting of ten randomly selected plants by using Portable Laser Leaf Area Meter (CI-202).

3.2.3.4 Leaf width/diameter (cm)

Recorded the maximum width of the longest leaf of ten fully developed plants at 90 days after transplant by using Portable Laser Leaf Area Meter (CI-202). Cylindrical leaves were flatten before measurement.

3.2.3.5 Leaf area

Leaf area was measured by using Portable Laser Leaf Area Meter (CI-202) by placing the leaf on the palette and sliding the scanner over the leaf.

3.2.3.6 Neck thickness (mm)

Vernier caliper was used to measure neck thickness below the joint of leaf lamina and the measurements were expressed in centimeters. The observations recorded for all the ten plants in all the plots and averaged to get the mean values.

3.2.3.7 Number of Days to Maturity

The number of days was counted from day of planting to the day when more than half of the population in each block reached neck fall or leaf yellowing stage.

3.2.3.8 Fresh Bulb weight (g)

The bulbs from ten randomly selected plants were weighed individually on an electronic balance and the average fresh weight was computed and expressed as grams (g).

3.2.3.9 Polar diameter (mm)

The length between two polar ends of the bulb was recorded with the help of Vernier caliper and mean diameter was worked out from all the ten bulbs in each plot. It was expressed in centimeters (cm).

3.2.3.10 Equatorial diameter (cm)

The diameter at the maximum width of the bulb across the polar length was measured of all ten onion bulbs with the help of Vernier caliper and it was expressed in centimeters (cm).

3.2.3.11 Bulb shape index (B.S.I.)

The bulb shape index was worked out by dividing the polar diameter with equatorial diameter of the bulb.

$$\text{Bulb shape index} = \frac{\text{Polar diameter}}{\text{Equatorial diameter}}$$

The bulbs with index value 1 were considered as ‘globular’, those with less than 1as ‘flat’ and the bulbs with a value of more than 1 are considered as ‘torpedo’.

3.2.3.12 Total soluble solids (%)

The total soluble solid content was recorded with the help of digital refractometer (Attago, Japan). The average content was worked out from all the 10 bulbs in triplicates and it was expressed in percentage.

3.2.3.13 Dry matter (%)

For the estimation of dry matter, 100 gm of fresh bulb sample (excluding outer skin) were sliced from all the five competent bulbs and the sliced samples were kept in the hot air oven for 48 hours at 60 ^{0}C. The dry matter content in percent was worked out.

3.2.3.14 Doubles or Deformed bulbs (%)

The bulbs having splits or doubles were recorded after the harvest. Then the percentage of doubles/splits was worked out for each block.

3.2.3.15 Colour of foliage

Colour of foliage recorded on fully developed plants at 90 days after transplant as per visual observation.

S. no.	Colour	Colour Code
1	Light green	1
2	Yellow green	2
3	Green	3
4	Grey green	4
5	Dark green	5
6	Bluish green	6
7	Purplish green	7
8	Other	9

3.2.3.16 Degree of leaf waxiness

The degree of leaf waxiness assigned as per the visual observation according to the plant descriptor for *alliums.*

S. no.	Degree of leaf waxiness	Waxiness code
1	Weak	3
2	Medium	5
3	Strong	7

3.2.3.17 Population uniformity of bulb shape

Recorded on harvested bulbs with dry skin.

S. no.	Population uniformity of bulb shape	Uniformity code
1	Uniform (homogeneous)	1
2	Variable	2
3	Highly variable	3

3.2.2.1 Bulb skin colour

Colours of the bulbs were assigned based on the visual observation of harvested bulbs with dry skin.

S. no.	Bulb skin colour	Colour code
1	White	1
2	Yellow	2
3	Yellow, light brown	3
4	Light brown	4
5	Brown	5
6	Dark brown	6
7	Light violet	7
8	Dark violet	8
9	99 Other(specify in descriptor 7.4 Remarks)	99

3.2.4.1 Statistical analysis

Morphological variations and relationship among onion germplasms in relation to quantitative and qualitative traits on the studied parameters were analyzed using D^2 statistics [108]. One way ANOVA with 2-tail Tukey's HSD at 0.05 levelo of significance was carried out using SPSS 21.0. The data of both years were pooled due to non-significant variation and subjected to PCA. Principal component analysis (PCA) was used to ordinate population means allowing for variance and covariance among genotypes 95]. For each population average Euclidean distance was calculated and resultant distance matrix was used to create a dendrogram using UPGMA method [124].

3.2.4.2 Genetic divergence analysis

The genetic divergence in twenty-six genotypes was estimated using Mahalanobis D^2 statistic [108] followed by Rao [148].

$$D^{2} = \Sigma\Sigma\left(\lambda^{ij}\right)^{p}_{i=1}\delta_{i}\delta_{j}{}^{p}_{j=1}$$

Where,

λ^{ij} =Reciprocal matrix to the common dispersion matrix.

δ_i = Difference between the mean values of the two populations for i^{th}character and

δ_j = Difference between the mean values of the two populations for j^{th}character.

parameter D^2can be calculated as D^2-statistics [148].

$D^2 = \sum\sum \delta_{IJ}, d_i d_J$ = Sample estimate of X_{ij}

Where,

δ_{IJ} = Sample estimates of X^{ij}

d_i = Sample estimates of δ_I

d_J = Sample estimates of δ_J

Unstandardized and correlated variables (mean value of character) were transformed into standardized uncorrelated variables. After transformation X_1, X_2, …………..Xp variable (unstandardized and correlated) becomes Y_1, Y_2, ………………….Yp variable (standardized and uncorrelated variables). This transformation was done according to the square root of Dwyer, described [148]. The variable transformations was done because this formula requires the inversion of ‘n’ order of determinants and then evaluation of (n+1)/2 term whose sum is D^2.

From the newly transformed uncorrelated variables, the square of the distance was computed using the formula,

$D2 = \sum (\bar{Y}_{1i} - \bar{Y}_{2i})^2$

Where,

$\bar{Y}_{1i}$ = Vector of transformed mean values, for first genotype

$\bar{Y}_{2i}$ = Vector of transformed mean values, for second genotype

The square root of the D^2 values gives the generalized distance (D) between the two populations. The D^2 values were arranged in a matrix form. The significance of D^2 values between any two populations was tested using the following formula.

$$F = \frac{(n_1 + n_2 - p - 1)}{(n_1 + n_2 - 2)\,P} \times \frac{(n_1\, n_2)\, D^2}{(n_1 + n_2)}$$

This computed F was compared with table F value at 5 per cent and 1 per cent levels of significance with P(number of characters) and $(n_1 + n_2 - p - 1)$ degrees of freedom.

3.2.4.3 Determination of population constellation

All the $n(n-1)/2$ D^2 values were taken for determining the population groups. This was realized by using Tocher's method as described by Rao [148]. The criterion used in clustering by this is that any two varieties belonging to the same cluster, should at least, in average, show a smaller D^2 value than those belonging to different clusters. As per the device, it was to start with two closely associated population and find a third population, which had the smallest average D^2 from these two. Similarly, the fourth was chosen to have a smallest average D^2 from the first three and so on. The permissible increase in D^2 values for clustering into the same group was fixed approximately nearer the maximum D^2 value shown by a population to the nearest population. This procedure was continued till D^2 values of all the pairs of genotypes were exhausted. After the formation of the clusters inter and intra cluster distance was calculated. The square root of the average D^2 values obtained from the above represents the distance (D) between and within clusters.

3.3 Results and Discussion

3.3.1 Genetic Variability for Quantitative and Qualitative traits

The germplasm were found to be rich in variability for all the studied characters. The perusal of data given in table 3.2 indicates that the plant height ranged from 31.55 to 66.26 cm and 23.77 to 60.21 cm in both the years. The maximum plant height (66.26cm, 60.21cm) was found in IC-0391544 in both the years. The minimum plant height (31.55cm, 23.77cm) was recorded in IC-0588677 during both the years.

Table 3.2: Performance of twenty-six onion genotypes for plant height and number of leaves at Leh

S.no.	Genotypes	Plant Height (cm)		Number of Leaves/plant	
		2013	**2014**	**2013**	**2014**
1.	IC-0279582	52.68 ± 4.93^{f}	45.10 ± 4.79^{fg}	**16.64 ± 2.45^{m}**	**14.98 ± 1.04^{l}**
2.	IC-0035182	54.42 ± 5.00^{f}	46.64 ± 5.16^{fg}	13.34 ± 1.56^{ijklm}	11.62 ± 1.06^{ghijk}
3.	IC-0035851	49.62 ± 4.87^{def}	43.04 ± 4.73^{efg}	12.20 ± 1.64^{efghijk}	10.02 ± 1.39^{efghij}
4.	IC-0035856	39.55 ± 0.89^{abcd}	32.56 ± 0.83^{abcde}	9.74 ± 0.76^{cdefgh}	7.86 ± 0.40^{abcdef}
5.	IC-0035891	55.48 ± 4.95^{fg}	47.90 ± 4.88^{gh}	10.42 ± 1.49^{defghi}	8.64 ± 1.60^{abcdefg}
6.	IC-0035940	66.22 ± 4.51^{g}	58.64 ± 4.44^{hi}	12.70 ± 1.00^{ghijkl}	10.48 ± 1.12^{fghij}
7.	IC-0035992	48.38 ± 7.56^{def}	40.80 ± 7.24^{efg}	9.00 ± 0.93^{bcde}	6.92 ± 0.86^{abcde}
8.	IC-0038823	40.40 ± 4.44^{abcde}	32.64 ± 4.43^{abcde}	9.34 ± 1.23^{bcdef}	8.40 ± 1.27^{abcdef}
9.	IC-0047928	47.80 ± 4.74^{def}	40.01 ± 4.73^{defg}	12.74 ± 0.84^{hijkl}	11.82 ± 0.68^{hijk}
10.	IC-0047940	45.98 ± 4.21^{cdef}	38.21 ± 4.22^{cdefg}	10.20 ± 1.27^{defghi}	8.94 ± 0.94^{bcdefgh}
11.	IC-0279180	45.02 ± 3.76^{bcdef}	37.26 ± 3.76^{bcdef}	11.24 ± 1.73^{efghij}	10.44 ± 1.54^{fghij}
12.	IC-310990	40.42 ± 6.74^{abcde}	32.65 ± 6.73^{abcde}	10.64 ± 1.25^{defghi}	9.84 ± 1.55^{defghij}
13.	IC-0338582	35.54 ± 1.30^{abc}	27.96 ± 1.41^{abc}	9.40 ± 2.70^{bcdefg}	8.84 ± 1.78^{bcdefgh}
14.	IC-0356095	34.67 ± 1.33^{ab}	26.89 ± 1.32^{abc}	7.39 ± 0.71^{abcd}	6.78 ± 0.53^{abcd}
15.	IC-0369521	36.00 ± 5.67^{abc}	28.23 ± 5.65^{abc}	6.40 ± 1.29^{ab}	6.48 ± 1.25^{abc}
16.	IC-0374706	55.28 ± 4.21^{fg}	47.52 ± 4.19^{gh}	14.14 ± 1.47^{jklm}	12.68 ± 1.80^{jkl}
17.	IC-0374724	34.50 ± 3.01^{ab}	27.82 ± 2.20^{abc}	15.44 ± 1.27^{lm}	14.06 ± 1.58^{kl}
18.	IC-0391544	**66.26 ± 7.52^{g}**	**60.21 ± 8.31^{i}**	9.72 ± 0.73^{bcdefgh}	9.42 ± 1.32^{cdefghi}
19.	IC-0392640	48.68 ± 8.57^{def}	41.91 ± 8.92^{efg}	11.92 ± 0.91^{efghijk}	11.62 ± 1.02^{ghijk}
20.	IC-0392647	35.74 ± 2.43^{abc}	29.06 ± 4.09^{abcd}	6.76 ± 0.81^{abc}	6.18 ± 0.60^{ab}
21.	IC-0440229	51.28 ± 4.45^{ef}	45.43 ± 3.70^{fg}	15.40 ± 1.98^{lm}	14.26 ± 2.28^{kl}
22.	IC-0512324	41.22 ± 3.05^{abcde}	35.34 ± 3.19^{bcdef}	9.60 ± 0.98^{bcdefgh}	9.22 ± 1.12^{bcdefghi}
23.	IC-0524211	33.80 ± 2.38^{ab}	26.02 ± 2.34^{ab}	12.58 ± 1.09^{fghijkl}	12.28 ± 1.10^{9ijkl}
24.	IC-0588677	31.55 ± 3.67^{a}	23.77 ± 3.69^{a}	5.34 ± 1.20^{a}	5.54 ± 0.52^{a}
25.	IC-0039039	55.90 ± 3.68^{fg}	48.12 ± 3.69^{gh}	14.60 ± 0.98^{klm}	14.18 ± 2.13^{kl}
26.	Local check	50.62 ± 4.87^{def}	42.84 ± 4.76^{efg}	12.80 ± 1.53^{hijkl}	11.66 ± 1.33^{ghijk}
	Range	31.55-66.26	23.77-60.21	5.34-16.64	5.54-14.06
	Total	46.04±10.44	38.71±10.54	11.14±3.13	10.12±2.89

Values represented as mean ± SD; in each column, values having different superscripts are significantly different at $p<0.05$, as measured by 2-sided Tukey's HSD among genotypes.

The data obtained for number of leaves per plant in onion genotypes have been tabulated in Table 3.2. The data reveal that the number of leaves per plant varied from 5.34 to 16.64 and 5.54 to 14.06 during 2013 and 2014, respectively. The maximum number of leaves per plant (16.64, 14.06) was found in IC-0279582 in both the years. The minimum number of leaves per plant (5.34, 5.54) was obtained in IC-0588677 in both the years.

Table 3.3: Performance of twenty-six onion genotypes for leaf length and leaf width at Leh

S.no.	Genotypes	Leaf Length (cm) 2013	2014	Leaf width (cm) 2013	2014
1.	IC-0279582	32.62±2.45^{abcdef}	29.54±2.12^{abcd}	0.72±0.08^{a}	0.61±0.06^{a}
2.	IC-0035182	45.15±7.69^{fgh}	40.96±7.73^{bcdef}	1.08±0.18^{ab}	1.03±0.07^{ab}
3.	IC-0035851	40.31±3.46^{cdefgh}	36.43±2.24^{abcdef}	1.29±0.24^{ab}	1.26±0.28^{abc}
4.	IC-0035856	35.82±5.86^{abcdefg}	32.07±5.36^{abcde}	3.16±0.48^{e}	3.14±0.47^{f}
5.	IC-0035891	39.72±4.00^{bcdefgh}	37.05±6.10^{abcdef}	1.21±0.18^{ab}	1.18±0.13^{ab}
6.	IC-0035940	51.44±4.71^{hi}	48.67±4.69^{fg}	1.10±0.15^{ab}	1.05±0.14^{ab}
7.	IC-0035992	46.90±3.02^{gh}	44.98±3.32^{efg}	1.28±0.25^{ab}	0.99±0.35^{ab}
8.	IC-0038823	39.56±13.96^{bcdefg}	35.93±12.18^{abcdef}	2.48±0.30^{de}	2.25±0.21^{def}
9.	IC-0047928	42.60±5.07^{efgh}	37.93±5.79^{abcdef}	1.40±0.25^{ab}	1.22±0.21^{ab}
10.	IC-0047940	42.73±3.56^{efgh}	38.51±4.62^{abcdef}	1.19±0.31^{ab}	1.04±0.30^{ab}
11.	IC-0279180	41.40±3.46^{defgh}	36.79±4.44^{abcdef}	1.32±0.15^{ab}	1.08±0.25^{ab}
12.	IC-310990	37.23±6.75^{abcdefg}	35.98±6.32^{abcdef}	1.21±0.21^{ab}	1.16±0.26^{ab}
13.	IC-0338582	28.10±2.56^{abc}	27.35±2.59^{ab}	2.63±0.30^{de}	2.43±0.37^{def}
14.	IC-0356095	27.06±4.19^{ab}	26.34±4.56^{ab}	2.91±0.40^{e}	2.71±0.51^{ef}
15.	IC-0369521	29.78±3.81^{abcd}	27.64±2.80^{ab}	2.79±0.42^{e}	2.58±0.60^{ef}
16.	IC-0374706	50.23±3.30^{hi}	45.86±2.67^{efg}	1.55±0.15^{ab}	1.32±0.24^{abc}
17.	IC-0374724	30.73±2.86^{abcde}	28.82±2.30^{abc}	1.02±0.15^{ab}	0.09±0.04^{ab}
18.	IC-0391544	**60.27±6.80^{i}**	**57.54±6.79^{g}**	1.20±0.08^{ab}	1.01±0.08^{ab}
19.	IC-0392640	45.56±6.81^{gh}	43.34±7.44^{cdefg}	**5.90±1.43^{f}**	**5.39±1.30^{g}**
20.	IC-0392647	31.62±4.00^{abcde}	29.86±3.75^{abcd}	2.46±0.49^{cde}	2.16±0.45^{cde}
21.	IC-0440229	46.97±4.66^{gh}	44.46±4.68^{defg}	1.17±0.13^{ab}	0.97±0.09^{ab}
22.	IC-0512324	34.70±4.83^{abcdefg}	32.54±5.26^{abcde}	3.04±0.32^{e}	2.76±0.39^{ef}
23.	IC-0524211	30.84±1.99^{abcde}	27.10±1.40^{ab}	0.89±0.17^{a}	0.77±0.64^{ab}
24.	IC-0588677	24.52±7.96^{a}	24.29±7.09^{a}	1.84±0.30^{bcd}	1.60±0.34^{bcd}
25.	IC-0039039	52.12±3.13^{hefgi}	46.18±3.00^{efg}	1.15±0.11^{ab}	0.99±0.13^{ab}
26.	Local check	43.33±2.29^{hijkl}	32.26±18.19^{abcde}	0.87±0.08^{a}	0.81±0.14^{ab}
	Range	24.52-60.27	24.29-57.54	0.72-5.90	0.61-5.39
	Total	39.67±9.97	36.48±9.88	1.80±1.16	1.63±1.09

Values represented as mean ± SD; in each column, values having different superscripts are significantly different at $p<0.05$, as measured by 2-sided Tukey's HSD among genotypes

Leaf length in onion genotypes ranged from 24.52 to 60.27 cm and from 24.29 to 57.54 cm during 2013 and 2014, respectively (Table 3.3). The greatest leaf length (60.27cm, 57.54 cm) was found in IC-0391544 in both the years. In IC-0588677, the smallest leaf length (24.52cm, 24.29cm) was obtained in both the years. Leaf width ranged from 0.72 to 5.90 cm and 0.61 to 5.39 cm during 2013 and 2014, respectively (Table 3.3). In IC-0392640, greatest leaf width (5.90, 5.39 cm) was found while lowest was (0.72, 0.62 cm) in IC-0279582 in both the years.

The chlorophyll content ranged from 36.81 to 46.64 cci and 34.93 to 43.18 cci during 2013 and 2014(Table 3.4). The maximum chlorophyll content (46.64cci, 43.18cci) was observed in IC-0035940 whereas lowest (36.81cci, 34.93cci) was observed in IC-0440229 during both the years. The results showed that the days to maturity ranged from 131.80 to 150.40 and 135.00 to 154.20 during 2013 and 2014 respectively (Table 3.4). The maximum days to maturity (150.40, 154.20) was taken in IC-0038823 while minimum (131.80, 135) in IC-0374724 during both the years.The double and deformed bulbs resulted in deteriorating quality as well as shelf life.

The double/deformed bulb ranged from 22.00 to 97.55 and 28.31 to 99.07 in 2013 and 2014 (Table 3.5). The maximum double/deformed bulb (97.55, 99.06) was found in the Local Cultivar while minimum (22.00, 28.31) was found in IC-0588677 during both the years. Neck thickness is an important parameter that dictates the storability qualities of onion varieties. The onion genotype showed high variability in neck thickness. It ranged from 0.62 to 2.73 cm and 0.94 to 2.96 cm during the years 2013 and 2014, respectively (Table 3.5). The greatest neck thickness (2.73, 2.96 cm) was observed in IC-0392640 whereas the lowest (0.62, 0.94 cm) was observed in IC-0588677 during both the years. The Total soluble solid ranged from 6.82 to 14.06% and 9.20 to 16.25 % during 2013 and 2014 respectively (Table 3.6).

The highest total soluble solids (14.06, 16.25%) was found in IC-0512324 whereas lowest (6.82, 9.20%) was found in IC-0338582 during the both years. The dry matter content ranged from 8.74 to 15.37 % and 11.25 to 17.22 % during the 2013 and 2014, respectively (Table 3.6). The maximum dry matter content (15.37, 17.22 %) was found in IC-0512324 while the lowest (8.74, 11.25 %) in IC-0338582 in both the years. Polar diameter ranged from 2.60 to 7.22 cm and 2.15 to 6.83 cm during 2013 and 2014 respectively (Table 3.7). Maximum polar diameter (7.22, 6.83 cm) was found in IC-0338582. Minimum polar diameter (2.60, 2.15 cm) was obtained in IC-0391544 in both the years. The equatorial diameter ranged from 2.40 to 7.02 cm and 2.05 to 6.63 cm during both the years respectively (Table 3.7). The greatest equatorial diameter (7.02, 6.63 cm) was obtained in IC-0392640 while smallest (2.40, 2.05 cm) in IC-0035182 during both the years.

Table 3.4: Performance of twenty six onion genotypes for Chlorophyll content and Days to maturity at Leh

S.no.	Genotypes	Chlorophyll Content (cci)		Days to Maturity	
		2013	2014	2013	2014
1.	IC-0279582	40.08 ± 1.08^{abcdef}	36.66 ± 1.71^{ab}	133.20 ± 0.45^{ab}	135.80 ± 2.49^{abc}
2.	IC-0035182	37.22 ± 2.44^{abc}	36.98 ± 2.60^{ab}	135.00 ± 1.41^{bcdef}	138.60 ± 2.07^{bcde}
3.	IC-0035851	43.46 ± 2.26^{defg}	39.42 ± 2.44^{ab}	132.00 ± 1.41^{a}	135.20 ± 1.48^{a}
4.	IC-0035856	41.65 ± 2.00^{abcdefg}	39.44 ± 2.27^{ab}	138.60 ± 0.55^{hi}	140.40 ± 0.55^{def}
5.	IC-0035891	37.83 ± 2.70^{abcd}	35.98 ± 2.96^{ab}	135.00 ± 0.71^{bcdef}	137.80 ± 1.64^{abcd}
6.	IC-0035940	**46.64 ± 1.11^{f}**	**43.18 ± 0.68^{b}**	135.60 ± 1.14^{defg}	137.00 ± 1.22^{abc}
7.	IC-0035992	39.52 ± 2.66^{abcde}	37.87 ± 2.88^{ab}	136.40 ± 0.89^{efg}	137.60 ± 2.07^{abcd}
8.	IC-0038823	44.90 ± 3.91^{efg}	40.67 ± 4.85^{ab}	150.40 ± 0.89^{m}	154.20 ± 1.30^{k}
9.	IC-0047928	41.10 ± 2.29^{abcdefg}	37.77 ± 2.29^{ab}	133.40 ± 0.55^{abc}	138.00 ± 1.58^{abcd}
10.	IC-0047940	37.60 ± 2.11^{abcd}	34.98 ± 2.38^{a}	133.60 ± 0.89^{abcd}	137.60 ± 0.89^{abcd}
11.	IC-0279180	41.52 ± 2.22^{abcd}	39.00 ± 2.27^{ab}	133.60 ± 0.89^{abcd}	137.00 ± 0.71^{abc}
12.	IC-310990	36.85 ± 2.02^{abcdefg}	34.97 ± 4.24^{a}	132.00 ± 1.00^{a}	135.20 ± 0.84^{a}
13.	IC-0338582	39.87 ± 2.16^{abcde}	36.34 ± 2.66^{ab}	142.40 ± 1.34^{k}	144.80 ± 1.30^{i}
14.	IC-0356095	40.19 ± 3.20^{abcdef}	37.47 ± 2.81^{ab}	146.60 ± 0.89^{l}	152.20 ± 0.45^{jk}
15.	IC-0369521	42.23 ± 3.33^{abcdefg}	38.58 ± 4.49^{ab}	146.80 ± 0.84^{l}	149.20 ± 1.10^{j}
16.	IC-0374706	46.04 ± 1.14^{fg}	40.71 ± 2.71^{ab}	134.60 ± 0.89^{bcde}	138.00 ± 1.58^{abcd}
17.	IC-0374724	37.55 ± 2.02^{abcd}	34.99 ± 2.91^{a}	**131.80 ± 1.10^{a}**	**135.00 ± 1.52^{ab}**
18.	IC-0391544	39.14 ± 2.78^{abcde}	38.41 ± 2.74^{ab}	137.00 ± 0.71^{fgh}	140.40 ± 0.89^{def}
19.	IC-0392640	41.12 ± 4.28^{abcdefg}	37.75 ± 2.67^{ab}	139.60 ± 0.55^{ij}	143.40 ± 0.89^{fgi}
20.	IC-0392647	44.80 ± 3.09^{efg}	42.70 ± 3.05^{b}	137.40 ± 0.55^{gh}	141.40 ± 1.14^{efg}
21.	IC-0440229	36.81 ± 2.28^{a}	34.93 ± 1.98^{a}	135.80 ± 0.84^{efg}	137.60 ± 1.82^{abcd}
22.	IC-0512324	43.01 ± 1.41^{bcdefg}	40.79 ± 3.83^{ab}	136.60 ± 0.55^{efgh}	139.00 ± 1.58^{cde}
23.	IC-0524211	39.98 ± 3.45^{abcde}	36.85 ± 4.04^{ab}	133.00 ± 0.71^{ab}	135.20 ± 0.84^{a}
24.	IC-0588677	43.12 ± 3.14^{cdefg}	39.30 ± 4.96^{ab}	135.40 ± 0.55^{cdefg}	137.60 ± 1.14^{abcd}
25.	IC-0039039	39.90 ± 2.40^{abcdef}	38.04 ± 2.60^{ab}	133.60 ± 0.55^{abcd}	135.60 ± 0.89^{ab}
26.	Local check	41.24 ± 2.19^{abcdefg}	40.20 ± 1.66^{ab}	141.60 ± 0.89^{jk}	144.20 ± 1.48^{gi}
	Range	36.81-46.64	34.93-43.18	131.80-150.40	135.00-154.20
	Total	40.90±3.60	38.19±3.57	136.96±4.90	139.94±5.26

Values represented as mean ± SD; in each column, values having different superscripts are significantly different at $p<0.05$, as measured by 2-sided Tukey's HSD among genotypes

Table 3.5: Performance of twenty-six onion genotypes for Double/deformed bulb and Neck thickness at Leh

S.no.	Genotypes	Double/deformed Bulb (%)		Neck Thickness (cm)	
		2013	2014	2013	2014
1.	IC-0279582	33.10 ± 1.92^{bcde}	40.58 ± 3.29^{bcd}	1.45 ± 0.13^{efg}	1.73 ± 0.13^{def}
2.	IC-0035182	56.50 ± 4.73^{hi}	61.34 ± 4.37^{f}	1.38 ± 0.11^{def}	1.62 ± 0.11^{cdef}
3.	IC-0035851	74.30 ± 9.36^{jk}	79.61 ± 8.53^{ij}	1.24 ± 0.06^{bcde}	1.59 ± 0.08^{bcde}
4.	IC-0035856	33.20 ± 2.20^{cde}	40.27 ± 2.60^{bcd}	0.81 ± 0.12^{a}	1.15 ± 0.11^{abc}
5.	IC-0035891	53.60 ± 3.21^{hi}	61.12 ± 2.82^{f}	2.15 ± 0.26^{jk}	2.19 ± 0.59^{fg}
6.	IC-0035940	69.00 ± 4.83^{j}	72.29 ± 3.94^{ghi}	1.70 ± 0.15^{fghi}	2.17 ± 0.30^{fg}
7.	IC-0035992	58.80 ± 2.64^{i}	65.10 ± 3.81^{fgh}	1.88 ± 0.21^{hij}	2.10 ± 0.10^{fg}
8.	IC-0038823	26.20 ± 0.57^{abcd}	31.99 ± 2.39^{ab}	0.86 ± 0.31^{ab}	1.14 ± 0.38^{abc}
9.	IC-0047928	39.60 ± 3.52^{efg}	43.78 ± 2.53^{cd}	2.45 ± 0.15^{klm}	2.88 ± 0.15^{h}
10.	IC-0047940	54.90 ± 2.41^{hi}	63.41 ± 4.94^{fg}	2.09 ± 0.16^{ijk}	2.50 ± 0.18^{gh}
11.	IC-0279180	68.60 ± 5.40^{j}	74.30 ± 4.36^{hi}	2.60 ± 0.09^{lm}	2.95 ± 0.16^{h}
12.	IC-310990	54.90 ± 2.82^{hi}	61.05 ± 4.20^{f}	2.25 ± 0.20^{jkl}	2.51 ± 0.15^{gh}
13.	IC-0338582	26.90 ± 1.08^{abcd}	33.41 ± 1.83^{abc}	0.95 ± 0.18^{abc}	1.44 ± 0.21^{abcd}
14.	IC-0356095	33.80 ± 3.53^{def}	38.67 ± 2.93^{abcd}	0.99 ± 0.15^{abcd}	1.46 ± 0.14^{abcd}
15.	IC-0369521	32.28 ± 3.68^{bcde}	35.31 ± 5.60^{abc}	0.69 ± 0.03^{a}	1.02 ± 0.06^{ab}
16.	IC-0374706	42.60 ± 1.71^{fg}	47.63 ± 3.39^{de}	1.85 ± 0.12^{ghij}	2.14 ± 0.25^{efg}
17.	IC-0374724	40.60 ± 4.55^{efg}	46.74 ± 7.22^{de}	2.12 ± 0.13^{jk}	2.53 ± 0.10^{gh}
18.	IC-0391544	48.40 ± 1.98^{gh}	54.55 ± 2.20^{ef}	2.42 ± 0.17^{klm}	2.42 ± 0.44^{gh}
19.	IC-0392640	28.30 ± 4.54^{abcd}	37.55 ± 10.12^{abcd}	2.73 ± 0.36^{m}	2.96 ± 0.36^{h}
20.	IC-0392647	24.50 ± 4.65^{abc}	30.44 ± 4.43^{ab}	0.73 ± 0.03^{a}	1.11 ± 0.09^{abc}
21.	IC-0440229	29.90 ± 1.29^{abcd}	33.78 ± 3.45^{abc}	1.38 ± 0.21^{def}	1.81 ± 0.20^{def}
22.	IC-0512324	23.90 ± 3.07^{ab}	30.11 ± 3.37^{ab}	1.03 ± 0.11^{abcd}	1.27 ± 0.08^{abcd}
23.	IC-0524211	29.30 ± 1.04^{abcd}	34.88 ± 2.32^{abc}	1.58 ± 0.13^{efgh}	2.09 ± 0.32^{efg}
24.	IC-0588677	**22.00 ± 2.32^{a}**	**28.31 ± 3.05^{a}**	**0.62 ± 0.07^{a}**	**0.94 ± 0.10^{a}**
25.	IC-0039039	79.70 ± 6.45^{k}	88.51 ± 4.66^{jk}	2.21 ± 0.19^{jkl}	2.49 ± 0.25^{gh}
26.	Local check	97.55±4.18l	99.07 ± 0.81^{k}	1.34 ± 0.11^{cdef}	1.67 ± 0.10^{cdef}
	Range	22.00-97.55	28.31-99.07	0.62-2.73	0.94-2.96
	Total	45.48±20.00	51.30±19.79	1.60±0.65	1.92±0.65

Values represented as mean ± SD; in each column, values having different superscripts are significantly different at $p<0.05$, as measured by 2-sided Tukey's HSD among genotypes

Table 3.6: Performance of twenty-six onion genotypes for Total soluble solids and Dry matter content at Leh

S.no.	Genotypes	Total Soluble Solids (%)		Dry Matter (%)	
		2013	2014	2013	2014
1.	IC-0279582	8.00±0.33^{ab}	10.35±0.37^{ab}	9.42±0.50^{a}	12.11±0.58^{a}
2.	IC-0035182	6.88±0.54^{a}	9.26±0.60^{a}	9.39±0.60^{a}	11.99±0.66^{a}
3.	IC-0035851	7.91±0.47^{ab}	10.28±0.45^{ab}	10.18±0.70^{ab}	12.87±0.74^{ab}
4.	IC-0035856	8.25±0.78^{ab}	10.44±0.84^{ab}	10.29±0.56^{ab}	12.83±0.14^{ab}
5.	IC-0035891	7.39±0.91^{ab}	9.79±0.84^{ab}	9.27±1.07^{a}	11.60±1.06^{a}
6.	IC-0035940	11.13±0.23^{de}	13.42±0.18^{def}	12.75±0.51^{cd}	15.43±0.48^{cd}
7.	IC-0035992	8.02±0.70^{ab}	10.36±0.69^{ab}	10.12±0.53^{ab}	12.71±0.12^{ab}
8.	IC-0038823	6.88±0.66^{a}	9.24±0.63^{a}	8.80±1.02^{a}	11.39±1.27^{a}
9.	IC-0047928	7.21±0.81^{ab}	9.63±0.81^{ab}	9.13±0.87^{a}	11.82±0.95^{a}
10.	IC-0047940	7.50±0.74^{ab}	9.88±0.71^{ab}	9.52±0.86^{a}	11.67±0.91^{a}
11.	IC-0279180	8.20±0.37^{ab}	10.60±0.36^{ab}	10.14±0.55^{ab}	12.92±0.55^{ab}
12.	IC-310990	12.56±0.29^{efg}	14.99±0.31^{fgh}	14.33±0.21^{de}	16.76±0.33^{d}
13.	IC-0338582	6.82±0.98^{a}	9.20±0.95^{a}	8.74±1.38^{a}	11.25±1.35^{a}
14.	IC-0356095	7.80±0.75^{ab}	10.19±0.75^{ab}	9.94±1.32^{a}	12.28±1.06^{a}
15.	IC-0369521	7.18±0.97^{ab}	9.53±1.03^{ab}	9.17±1.18^{a}	11.35±1.00^{a}
16.	IC-0374706	7.27±0.80^{ab}	9.67±0.79^{ab}	8.87±0.92^{a}	11.66±0.98^{a}
17.	IC-0374724	8.62±0.38^{bc}	10.92±0.33^{bc}	10.10±0.26^{ab}	12.89±0.29^{ab}
18.	IC-0391544	7.21±1.07^{ab}	9.60±1.03^{ab}	9.17±1.00^{a}	11.56±1.05^{a}
19.	IC-0392640	11.10±0.15^{de}	13.50±0.26^{def}	13.84±0.86^{cde}	15.91±0.50^{cd}
20.	IC-0392647	11.22±1.21^{def}	13.28±1.24^{de}	12.90±1.29^{cd}	15.42±1.42^{cd}
21.	IC-0440229	12.06±0.39^{ef}	14.59±0.34^{efg}	13.94±0.29^{cde}	16.64±0.20^{d}
22.	IC-0512324	**14.06±0.75^{f}**	**16.25±0.46^{h}**	**15.37±0.85^{e}**	**17.22±0.26^{d}**
23.	IC-0524211	12.81±0.18^{fg}	15.22±0.13^{gh}	14.27±0.33^{de}	16.91±0.27^{d}
24.	IC-0588677	11.30±0.43^{def}	13.70±0.43^{defg}	13.31±0.67^{cd}	15.72±0.48^{cd}
25.	IC-0039039	9.98±0.70^{cd}	12.34±0.75^{cd}	12.05±1.09^{bc}	14.15±1.09^{bc}
26.	Local check	8.00±0.81^{ab}	10.47±0.83^{ab}	9.50±0.96^{a}	12.62±0.62^{ab}
	Range	6.82-14.06	9.20-16.5	8.74-15.37	11.25-17.22
	Total	9.05±2.24	11.41±2.23	10.94±2.22	13.45±2.13

Values represented as mean ± SD; in each column, values having different superscripts are significantly different at $p<0.05$, as measured by 2-sided Tukey's HSD among genotypes

Table 3.7: Performance of twenty-six onion genotypes for Polar diameter and Equatorial diameter at Leh

S.no.	Genotypes	Polar Diameter (cm)		Equatorial Diameter (cm)	
		2013	2014	2013	2014
1.	IC-0279582	3.33 ± 0.09^{bc}	2.83 ± 0.34^{abc}	2.94 ± 0.12^{abcd}	2.68 ± 0.18^{abc}
2.	IC-0035182	3.15 ± 0.25^{abc}	2.62 ± 0.35^{abc}	2.40 ± 0.29^{a}	2.05 ± 0.29^{a}
3.	IC-0035851	3.60 ± 0.17^{c}	3.17 ± 0.32^{bcd}	3.00 ± 0.25^{abcd}	2.79 ± 0.25^{abcd}
4.	IC-0035856	6.29 ± 0.48^{g}	5.92 ± 0.46^{i}	6.78 ± 0.36^{g}	6.27 ± 0.42^{g}
5.	IC-0035891	3.12 ± 0.24^{abc}	2.71 ± 0.36^{abc}	3.01 ± 0.19^{abcd}	2.56 ± 0.18^{abc}
6.	IC-0035940	3.05 ± 0.22^{abc}	2.65 ± 0.22^{abc}	2.52 ± 0.31^{ab}	2.14 ± 0.21^{ab}
7.	IC-0035992	3.60 ± 0.15^{c}	3.24 ± 0.20^{cd}	3.62 ± 0.21^{de}	3.14 ± 0.22^{cd}
8.	IC-0038823	5.42 ± 0.30^{ef}	4.89 ± 0.37^{fgh}	6.64 ± 0.21^{g}	6.26 ± 0.28^{g}
9.	IC-0047928	2.98 ± 0.26^{abc}	2.59 ± 0.28^{abc}	2.71 ± 0.22^{abc}	2.49 ± 0.23^{abc}
10.	IC-0047940	3.24 ± 0.15^{abc}	2.64 ± 0.15^{abc}	2.90 ± 0.10^{abc}	2.58 ± 0.13^{abc}
11.	IC-0279180	3.21 ± 0.30^{abc}	2.75 ± 0.34^{abc}	3.19 ± 0.28^{bcd}	2.92 ± 0.34^{bcd}
12.	IC-310990	3.20 ± 0.23^{abc}	2.75 ± 0.28^{abc}	2.89 ± 0.11^{abc}	2.71 ± 0.05^{abc}
13.	IC-0338582	**7.22 ± 0.30^{h}**	**6.83 ± 0.36^{j}**	6.77 ± 0.37^{g}	6.32 ± 0.40^{g}
14.	IC-0356095	5.96 ± 0.27^{fg}	5.45 ± 0.26^{ghi}	6.63 ± 0.65^{g}	6.30 ± 0.69^{g}
15.	IC-0369521	6.22 ± 0.12^{g}	5.63 ± 0.24^{hi}	6.65 ± 0.29^{g}	6.28 ± 0.39^{g}
16.	IC-0374706	3.21 ± 0.07^{abc}	2.65 ± 0.22^{abc}	3.05 ± 0.16^{abcd}	2.59 ± 0.21^{abc}
17.	IC-0374724	3.20 ± 0.18^{abc}	2.52 ± 0.18^{abc}	3.09 ± 0.15^{abcd}	2.80 ± 0.16^{abcd}
18.	IC-0391544	2.60 ± 0.20^{a}	2.15 ± 0.38^{a}	3.36 ± 19^{cde}	3.08 ± 0.18^{cd}
19.	IC-0392640	6.04 ± 0.60^{fg}	5.50 ± 0.76^{hi}	**7.02 ± 0.60^{g}**	**6.63 ± 0.79^{g}**
20.	IC-0392647	6.16 ± 0.42^{g}	5.55 ± 0.38^{hi}	5.53 ± 0.24^{f}	5.40 ± 0.33^{ef}
21.	IC-0440229	4.31 ± 0.20^{d}	3.71 ± 0.21^{de}	3.35 ± 0.15^{cde}	3.04 ± 0.21^{cd}
22.	IC-0512324	5.18 ± 0.52^{e}	4.66 ± 0.50^{fg}	6.42 ± 0.27^{g}	6.09 ± 0.39^{fg}
23.	IC-0524211	3.28 ± 0.04^{abc}	2.61 ± 0.20^{abc}	4.04 ± 0.14^{e}	3.65 ± 0.27^{d}
24.	IC-0588677	4.87 ± 0.43^{de}	4.51 ± 0.45^{ef}	5.45 ± 0.40^{f}	5.00 ± 0.57^{e}
25.	IC-0039039	2.86 ± 0.12^{ab}	2.40 ± 0.11^{ab}	3.35 ± 0.14^{cde}	3.20 ± 0.47^{cd}
26.	Local check	3.60 ± 0.17^{c}	3.13 ± 0.23^{bcd}	3.00 ± 0.25^{abcd}	2.80 ± 0.33^{abcd}
	Range	2.60-7.22	2.15-6.83	2.40-7.02	2.05-6.63
	Total	4.19±1.38	3.69±1.39	4.24±1.67	3.91±1.65

Values represented as mean ± SD; in each column, values having different superscripts are significantly different at $p<0.05$, as measured by 2-sided Tukey's HSD among genotypes

The bulb shape index or the bulb dimensions are indirectly related to the yield and storage capacity of onion bulbs, bulb shape is an important selection criterion and the desired shape depends on the market preference. Kepkova and Uniocka[89] reported that onions with a diameter of 3.5 to 4.5 cm stored better than those with a diameter of 4.5 to 7.0 cm. Considerable variation was found in the bulb shape of onion genotypes. The preferred shape can vary from flat to globe to torpedo in different markets having different requirements. Bulb shape has become an important aspect of market acceptability as well as ease in packaging. The onion bulb shape was assessed by using the bulb shape index; which is the ratio of the bulb height to diameter (Table 3.8). The bulb shape index values of genotypes IC-0035856, IC-0035992, IC-0038823, IC-0356095, IC-0369521, IC-0391544, IC-0392640, IC-0512324, IC-0524211, IC-0588677, IC-0039039 were found to be less than 1, considered as flat (Table 3.8) while IC-0279582, IC-0035182, IC-0035851, IC-0035940, IC-0047928, IC-0338582, IC-0440229 and Local check were found to be more than 1, considered as torpedo. The bulb shape index values of genotypes IC-0035891, IC-0047940, IC-0279180, IC-0310990, IC-0374706, IC-0392647 were found to be 1 considered as globular (Table 3.8).

Table 3.8: Value of bulb shape index of twenty six onion Genotypes

S. no.	Genotypes	Value (2013)	Value (2014)	Bulb shape index	Shape
1	IC-0035856	0.92	0.94	<1	Flat
	IC-0035992	0.99	0.98		
	IC-0038823	0.81	0.78		
	IC-0356095	0.90	0.87		
	IC-0369521	0.93	0.90		
	IC-0391544	0.77	0.70		
	IC-0392640	0.86	0.83		
	IC-0512324	0.80	0.75		
	IC-0524211	0.81	0.72		
	IC-0588677	0.89	0.91		
	IC-0039039	0.85	0.75		
2	IC-0279582	1.13	1.05	>1	Torpedo
	IC-0035182	1.31	1.21		
	IC-0035851	1.20	1.14		
	IC-0035940	1.22	1.30		
	IC-0047928	1.09	1.05		
	IC-0338582	1.06	1.08		
	IC-0440229	1.28	1.22		
	Local check	1.20	1.13		
3	IC-0035891	1.04	1.05	1	Globular
	IC-0047940	1.01	1.02		
	IC-0279180	1.01	0.93		
	IC-0310990	1.01	0.98		
	IC-0374706	1.03	1.02		
	IC-0392647	1.01	1.03		

Figure 3.3: Potential genotypes from 26 accessions of onion.

Average bulb weight ranged from 33.82 to 98.57 g and 31.20 to 93.56 g during both the years (Table 3.9). Maximum average bulb weight (98.57, 93.56 g) was found in IC-0512324. Minimum average bulb weight (33.82, 31.20 g) was obtained in IC-0035851 in both the years. The results showed that the bulb yield ranged from 6.89 to 19.97 kg and 6.29 to 18.72 kg during 2013 and 2014, respectively. The highest bulb yield (19.97, 18.72 kg/plot) was found in IC-0512324 (Table 3.9, figure 3.3) and minimum (6.89, 6.29 kg/plot) in IC-0035851, respectively in both the years.

Table 3.9: Performance of twenty-six onion genotypes for Average bulb weight and Bulb yield at Leh

S.no.	Genotypes	Average Bulb Weight (g)		Bulb Yield (Kg/plot)	
		2013	**2014**	**2013**	**2014**
1.	IC-0279582	36.78±3.28^{a}	34.55±4.29^{a}	7.39±0.60^{a}	6.90±0.86^{a}
2.	IC-0035182	39.74±4.58^{ab}	37.24±4.98^{ab}	7.84±0.81^{a}	7.48±0.99^{abc}
3.	IC-0035851	33.82±2.54^{a}	31.20±2.69^{a}	6.89±0.38^{a}	6.29±0.79^{a}
4.	IC-0035856	86.54±6.90^{ef}	87.10±7.35^{def}	17.30±1.38^{de}	17.39±1.41^{efg}
5.	IC-0035891	53.82±5.46^{cd}	49.35±6.73^{bc}	10.76±1.09^{c}	9.99±1.38^{cd}
6.	IC-0035940	37.40±4.14^{a}	34.00±3.63^{a}	7.70±0.87^{a}	6.81±0.72^{a}
7.	IC-0035992	37.39±4.84^{a}	33.15±4.27^{a}	7.67±1.16^{a}	6.74±0.79^{a}
8.	IC-0038823	89.65±5.89^{efg}	86.12±5.88^{def}	17.93±1.18^{def}	17.27±1.23^{efg}
9.	IC-0047928	35.82±3.02^{a}	32.52±5.78^{a}	7.13±0.74^{a}	6.48±1.17^{a}
10.	IC-0047940	37.69±3.85^{a}	32.38±2.39^{a}	7.43±0.76^{a}	6.24±0.55^{a}
11.	IC-0279180	42.15±3.97^{abc}	37.57±3.78^{ab}	8.39±0.72^{abc}	7.50±0.80^{abc}
12.	IC-310990	44.23±4.29^{abcd}	37.75±6.22^{ab}	8.90±0.91^{abc}	7.54±1.24^{abcd}
13.	IC-0338582	88.76±11.34^{efg}	83.47±11.17^{def}	17.75±2.27^{def}	16.71±2.25^{efg}
14.	IC-0356095	97.90±6.80^{fg}	92.02±5.44^{ef}	19.78±1.36^{ef}	18.41±1.08^{fg}
15.	IC-0369521	98.23±2.65^{g}	93.16±3.14^{f}	19.84±0.53^{ef}	18.63±0.64^{g}
16.	IC-0374706	40.69±1.62^{ab}	37.21±1.97^{ab}	8.17±0.29^{ab}	7.32±0.32^{abc}
17.	IC-0374724	38.93±4.77^{a}	36.03±5.46^{ab}	7.64±1.10^{a}	7.21±1.10^{ab}
18.	IC-0391544	52.00±5.01^{bcd}	48.26±4.60^{bc}	10.50±0.85^{bc}	9.64±0.92^{bcd}
19.	IC-0392640	93.91±5.33^{efg}	86.28±4.90^{def}	18.78±1.06^{def}	17.27±0.99^{efg}
20.	IC-0392647	93.92±4.02^{efg}	89.40±2.09^{def}	18.78±0.80^{def}	17.85±0.42^{efg}
21.	IC-0440229	84.28±3.94^{e}	78.44±4.13^{d}	16.89±0.80^{d}	15.69±0.80^{e}
22.	IC-0512324	**98.57±8.12^{fg}**	**93.56±8.34^{f}**	**19.97±1.76^{f}**	**18.72±1.72^{g}**
23.	IC-0524211	83.00±3.34^{e}	78.06±1.23^{d}	16.63±0.62^{d}	15.59±0.26^{e}
24.	IC-0588677	83.46±8.44^{e}	79.17±9.40^{de}	16.58±1.50^{d}	15.84±1.88^{ef}
25.	IC-0039039	55.12±5.86^{d}	51.23±6.81^{c}	10.90±1.29^{c}	10.24±1.37^{d}
26.	Local check	34.02±1.78^{a}	31.54±5.52^{a}	6.69±0.38^{a}	6.31±1.10^{a}
	Range	33.82-98.57	31.20-93.56	6.89-19.97	6.29-18.72
	Total	62.30±25.88	58.07±25.33	12.47±5.18	11.61±5.07

Values represented as mean ± SD; in each column, values having different superscripts are significantly different at $p<0.05$, as measured by 2-sided Tukey's HSD among genotypes

Among the 26 onion genotypes studied, considerable variation was observed for all the important attributes viz. colour of foliage, degree of leaf waxiness, uniformity of bulb shape and colour of bulb skin under the study. The characterization of onion genotypes with respect to these qualitative traits is presented in Table 3.10. The difference between studied genotypes might be related to genetic makeup of the used cultivars [83]. Similar results were obtained by Akhtar et al. [5], Gemma et al.[59],Soleymani and Shahrajabian [182]

Table 3.10: Performance of twenty six onion genotypes for qualitative traits

S.no.	Genotypes	Colour of Foliage		Degree of Leaf Waxiness		Uniformity of Bulb Shape		Colour of Bulb Skin	
		2013	2014	2013	2014	2013	2014	2013	2014
1	IC-0279582	2,3,5	3,5	3,5	5	1	1	1	1
2	IC-0035182	3,5	2,3,5	5	3,5	1	1	1	1
3	IC-0035851	2,5	2,3,5	3,5	5	1	1	1	1
4	IC-0035856	2,5	2,5	3,5	3,5	2	2	1	1
5	IC-0035891	1,2	1,2,3	3,5	5	2	2	8,9	8,9
6	IC-0035940	2,5	2,3,5	5	3,5	2	2	8	8
7	IC-0035992	3,5	5	5,7	5,7	3	3	8	8
8	IC-0038823	3,5	5	5,7	3,5,7	1	1	8,9	8,9
9	IC-0047928	2,3,5	2,3,5	5	5	1	1	8	8
10	IC-0047940	1,2	1,2	5,7	2,3,5	1	1	8	8
11	IC-0279180	1,2	1	3,5	5	3	3	8	8
12	IC-310990	2,3	2,3	3,5	3,5	2	2	9	9
13	IC-0338582	1,2	1,2	3,5	3,5	1	1	8	8
14	IC-0356095	1,2	1,2	3	3	2	2	8	8
15	IC-0369521	3,5	3,5	3	3	1	1	4,5	4,5
16	IC-0374706	3,5	5	3,5	5	2	2	6	6
17	IC-0374724	2	2,3	5	5	3	3	4	4
18	IC-0391544	3,5	5	3	3,5	1	1	4	4
19	IC-0392640	5	5	5,7	3,5,7	1	1	3	3
20	IC-0392647	3,5	3,5	5	5,7	1	1	8,9	8,9
21	IC-0440229	1,2,3	1,2,3	3	3,5	1	1	9	9
22	IC-0512324	3	3,5	5	5,7	1	1	9	9
23	IC-0524211	5	3,5	5,7	5,7	1	1	9	9
24	IC-0588677	3,5	3,5	5	5	2	2	8	8
25	IC-0039039	5	3,5	3,5,7	3,5,7	3	3	1	1
26	Local check	3,5	3,5	5,7	5,7	3	3	1	1

Colour of foliage: 1=light green, 2=yellow green, 3= green, 4=grey-green, 5=dark green, 6=bluish green, 7=purplish green. **Degree of leaf waxiness**: 3=weak, 5=medium, 7=strong. **Uniformity of bulb shape**: 1=uniform, 2=variable, 3=highly variable. **Colour of bulb skin**: 1=white, 2=yellow, 3=yellow and light brown, 4=light brown, 5=brown, 6=dark brown, 8=light violet, 9=dark violet.

3.3.2 Correlation analysis among quantitative traits

Simple correlation coefficients between different characteristics of onion based on data of 26 genotypes are presented in table 3.11. Correlation analysis gives a tool to indirectly select the genotypes for important economic traits such as bulb yield and average bulb weight. Bulb yield was positively correlated 0.01 level of significance with Leaf width(r=0.692), chlorophyll content (r=0.230), days to maturity (r=0.597), TSS (r=0.276), dry matter (r=0.269), polar diameter (r=0.816) and equatorial diameter (r=0.885). On the other hand bulb yield was negatively correlated with number of leaves (r = -0.405), leaf length (r = -0.349), double/deformed bulbs (r = -0.726), neck thickness (r = -0.570) and bulb shape index (r =- 0.422). These characters should not be considered in selection criteria owing to their negative effect on bulb yield suggesting that the selection of these characters may not help in increasing the bulb yield. The results are in conformity with that reported by Mohanty [127], Rahman et al. [145], Trivedi et al. [192], Yaso [207], Singh at al. [175].

Table 3.11: Pearson's correlation coefficient between quantitative and qualitative traits of twenty-six onion genotypes

Traits	PH	NL	LL	LW	CC	MD	D/DB	NT	TSS	DM	PD	ED	BSI	ABW	BY
PH	1	0.480**	0.855**	-0.197*	0.237**	-0.244**	0.450**	0.342**	-0.228**	-0.224*	-0.523**	-0.523**	0.218*	-0.454**	-0.451**
NL		1	0.416**	-0.279**	-0.008	-0.419**	0.238**	0.395**	-0.019	-0.041	-0.510**	-0.522**	0.210*	-0.404**	-0.405**
LL			1	-0.084	0.275**	-0.160	0.411**	0.410**	-0.182*	-0.165	-0.464**	-0.412**	0.060	-0.352**	-0.349**
LW				1	0.290**	0.514**	-0.490**	-0.207*	0.074	0.107	0.739**	0.805**	-0.333**	0.692**	0.692**
CC					1	0.245**	-0.105	-0.364**	-0.116	-0.155	0.193*	0.220*	-0.075	0.229**	0.230**
MD						1	-0.306**	-0.481**	-0.325**	-0.317**	0.665**	0.699**	-0.242**	0.597**	0.597**
D/DB							1	0.406**	-0.183*	-0.165	-0.582**	-0.628**	0.309**	-0.726**	-0.726**
NT								1	0.022	0.046	-0.607**	-0.534**	-0.009	-0.570**	-0.570**
TSS									1	0.978**	0.029	0.091	-0.116	0.273**	0.276**
DM										1	0.043	0.102	-0.110	0.267**	0.269**
PD											1	0.907**	-0.116	0.817**	0.816**
ED												1	-0.498**	0.885**	0.885**
BSI													1	-0.421**	-0.422**
ABW														1	1.000**
BY															1

***Correlation is significant at the 0.05 level (2-tailed), **Correlation is significant at the 0.01 level (2-tailed). PH-Plant height; NL-Number of leaf; LL-Leaf length; LW-Leaf width; CC-Chlorophyll content; MD-Maturity days; D/DB-Double/deformed bulb; NT-Neck thickness; TSS-Total soluble solids; DM-Dry matter; PD-Polar diameter; ED-Equatorial diameter; BSI- Bulb shape index; ABW-Average bulb weight; BY-Bulb yield.**

3.3.3 Cluster analysis

26 onion genotypes grouped into four distinct clusters (Table 3.12) on the basis of D^2 value estimates of genetic divergence. Cluster I contained 2 genotypes and cluster II contained 10 genotypes. Whereas there were 2 genotypes in cluster III and 12 genotypes and Cluster IV.

Table 3.12: Distribution of twenty-six onion genotypes in different clusters based on Mahalanobis' D^2-values

S.no.	Cluster	Number of genotypes	Genotypes
1	I	2	IC-0392640 , IC-0440229
2	II	10	IC-0035856, IC-0338582, IC-0356095, IC-0369521, IC-0512324, IC-0588677, IC-0524211, IC-0374724, IC-0392647, IC-0038823
3	III	2	Local Cultivar, IC-0039039
4	IV	12	IC-0035851, IC-0035940, IC-0374706, IC-310990, IC-0279582, IC-0035182, IC-0035891, IC-0035992, IC-0047928, IC-0047940, IC-0279180, IC-0391544

Intra-cluster distance was highest (2.778) in Cluster II followed by cluster IV (2.345), cluster I (2.191) and cluster III (2.064) (Table 3.13). The intra cluster distances in all the four clusters were low, which indicate that genotypes of same cluster are closely related. While considering the inter-cluster distance (Table 3.13), utmost intercluster distance was noticed between clusters I and IV (6.129) followed by between clusters II and IV (5.675) and between cluters I and III (4.933). Minimum distance (2.542) was noticed between clusters I and II (Table 3.13). According to Ghaderi et al. [60], increasing parental distance entail a number of divergent alleles at gene loci. Upon crossing such parents recombination of these alleles at gene loci in the F2 and F3 generation, provide more prospects for the effective selection of new genotypes containing more yield factors. Therefore, the crossing of genotypes from these clusters with other clusters may produce higher amounts of heterotic expression in the first filial generations (F1's) and a wide range of variability in subsequent segregating (F2) populations. Akter et al. [7] found similar results.

Mean value of fifteen morphological traits in four different clusters are presented in table 3.14. This could be helpful for breeders for the selection of parents with objective of improvement of specific traits in future. The mean value of many economically important traits such as Bulb yield, Average bulb weight, polar and equatorial diameter, Leaf width were found highest for cluster II; whereas in this cluster, the values of undesirable traits such as neck thickness and Double/deformed bulbs were also minimum. Thus, genotypes of cluster II should be selected as parent in further improvement in these traits. On the basis of mean values of traits in cluster III genotypes of this cluster are suitable for improvement in traits like Days to maturity, TSS, Dry matter content on the basis of mean values of traits. Mean values of plant height, Leaf width and chlorophyll content were highest for cluster IV.

Table 3.13: Average intra- (bold face) and inter-cluster distance (D^2) of 26 onion genotypes

S. no.	Clusters	I	II	III	IV
1	I	**2.191**			
2	II	2.542	**2.778**		
3	III	4.933	3.649	**2.064**	
4	IV	6.129	5.675	4.645	**2.345**

Table 3.14: Mean of fifteen morphological traits in four clusters

S. no.	Traits	Clusters			
		I	II	III	IV
1	Plant Height (cm)	50.64	38.15	41.83	**55.43**
2	Number of Leaves	**12.90**	8.43	12.87	12.86
3	Leaf Length (Cm)	43.42	32.97	38.35	**46.33**
4	Leaf Width (Cm)	1.16	**3.02**	1.09	1.20
5	Chlorophyll content	39.14	42.32	37.88	**44.34**
6	Days to maturity	134.26	141.53	**133.60**	135.95
7	Double/Deformed Bulb (%)	53.38	**27.90**	38.03	70.86
8	Neck Thickness(cm)	1.02	**1.04**	1.74	1.53
9	TSS %	7.90	9.40	**12.48**	8.58
10	Dry matter %	9.83	11.37	**14.18**	10.32
11	Polar diameter (cm)	3.13	**5.93**	3.60	3.36
12	Equatorial Diameter (Cm)	3.06	**6.43**	3.43	2.89
13	Bulb shape index	1.03	0.92	1.07	1.17
14	Average bulb wt. (g)	42.94	**92.55**	70.50	36.48
15	Bulb yield kg/ plot	8.57	**18.52**	14.14	7.36

Crosses between parents from divergent clusters are expected to result in maximum heterosis and variability in genetic architecture of resulting plants [176]; [7]. In current study, Cluster II was found to be more divergent than the rest of clusters. As mentioned before in selection of parents the special advantage of each cluster and each genotype within a cluster depend on the specific objective of hybridization [36]. Thus, crosses involving Cluster II with any other cluster are suggested to exhibit high heterosis and could result in segregates with higher bulb yield.

3.3.4 Multivariate analysis

A dendrogram was constructed to display the similarity between morphological relatedness among different genotypes of onion based on the Euclidean distance from the morphological data matrix of two consecutive years. Dendrogram based on UPGMA method analysis grouped the genotype into two main clusters and four subclusters I, II, III and IV (Figure 3.4). Subcluster I represents the genotypes IC-0392640 and IC-0440229, subcluster II represents IC-0035856, IC-0338582, IC-0356095, IC-0369521, IC-0512324, IC-0588677, IC-0524211, IC-0374724, IC-0392647, IC-0038823, subcluster III represents Local Cultivar and IC-0039039 and subcluster IV represents the genotypes IC-0035851, IC-0035940, IC-0374706, IC-310990, IC-0279582, IC-0035182, IC-0035891, IC-0035992, IC-0047928, IC-0047940, IC-0279180, , IC-0391544. These initial groupings of the individuals show the best fit to the four distinct groups, but we could not determine which characters are responsible for these groupings. Therefore, we had to do further statistical evaluation with principal component analysis (PCA).

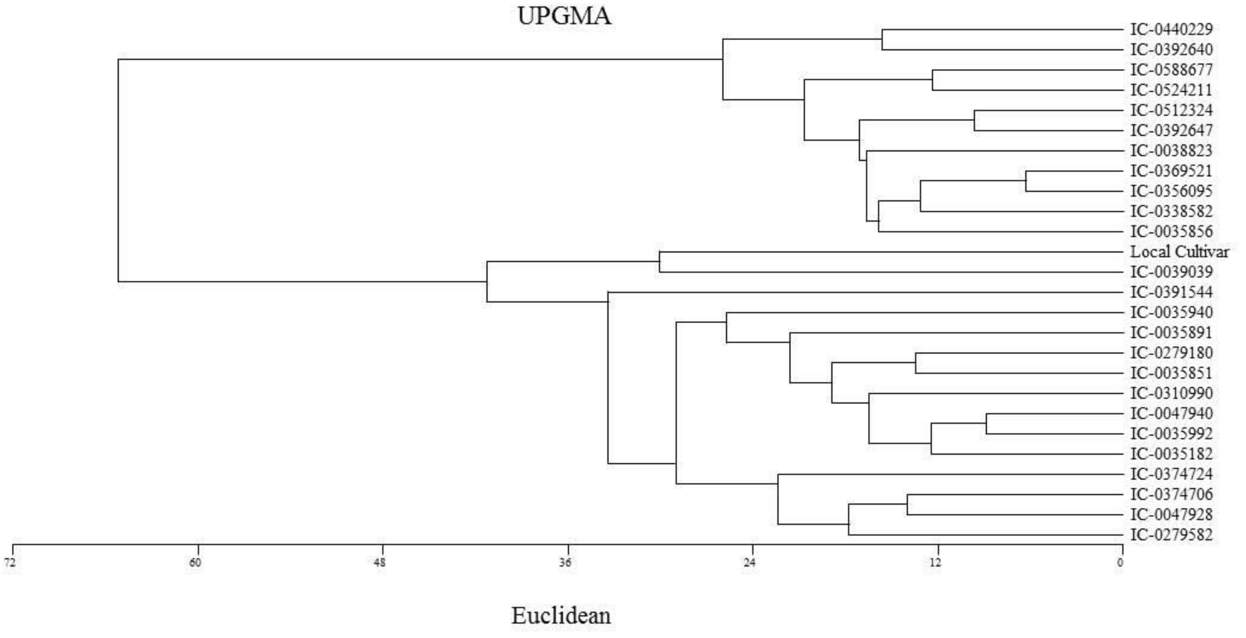

Figure 3.4: Dendogram showing the genotypic relationship among 26 accessions are based on morphological traits

PCA reveal the importance of the largest contributor to the total variation at each axis of differentiation [168]. The eigen values are used to determine the number of factors to be retained and sum of the eigen values is usually equal to the number of variables. We analyzed the PCA for 19 variables to discriminate the 26 onion varieties including Local cultivar. We found that principal component analysis extracted three PC's which contributed 95.61% of variation out of which PC1, PC2 and PC3 contribute 77.52 % , 10.72 % and 7.38 % of variability respectively among 26 accessions (Table 3.15). Characters with the largest absolute value closer to unity within the first principal component influence the clustering more than those with lower absolute value closer to zero According to Chahal and Gosal [36]. The data in table 3.15 indicates that, differentiation of the accessions into different clusters was because of relatively high contribution of few traits rather than small contribution from each character.

Table 3.15: Eigen values and Variable lodging

Particulars	**PC 1**	**PC 2**	**PC 3**
Eigenvalues	1014.28	140.27	96.54
Percentage	77.52	10.72	7.38
Cum. Percentage	77.52	88.24	95.61
Variables	**PC 1**	**PC 2**	**PC 3**
Plant Height (cm)	-0.2	0.17	0.009
Number of Leaves	-0.042	-0.044	0.067
Leaf Length (cm)	-0.158	0.216	0.61
Leaf Width (cm)	0.023	0.024	0.013
Chlorophyll content	0.011	0.046	0.033
Days to maturity	0.085	0.166	-0.019
Double/Deformed Bulb (%)	-0.546	0.037	-0.368
Neck Thickness(cm)	-0.011	-0.006	0.015
TSS %	0.021	0.014	0.692
Dry matter %	0.02	0.019	0.01
Polar diameter (cm)	0.036	0.025	-0.021
Equatorial Diameter (cm)	0.046	0.742	-0.016
Bulb shape index	-0.002	-0.002	-0.001
Average bulb weight (g)	0.773	0.567	0.048
Bulb yield kg/ plot	0.155	0.114	0.012
Colour of foliage	-0.002	0.013	0.054
Degree of leaf Waxiness	-0.008	-0.012	-0.002
Uniformity of Bulb shape	-0.011	0.015	-0.032
Colour of bulb skin	0.034	-0.063	0.002

As per table 3.15, PC1 had high positive component loading from the Average bulb weight, Bulb yield and high negative loading from the Leaf length, Double/deformed bulb while remaining traits in PC1 did not contribute; rather their effects were distributed among other PCs (Table 3.15, Figure 3.5). The positive and negative loading showed the presence of positive and negative correlation trends between the components and the variables. Therefore, the above mentioned characters which loaded highly positively or negatively contributed more to the diversity and they were the ones that were most differentiated. The traits which contributed more positively to PC2 were Leaf length, Equatorial diameter, Average bulb weight, however remaining traits in PC2 did not contribute. Rather, their effects were distributed among other PCs. The traits which contributed more positively to PC3 were TSS, Leaf length and high negative loading from Double /deformed bulb while remaining traits in PC3 did not contribute; their effect were distributed among other PCs.

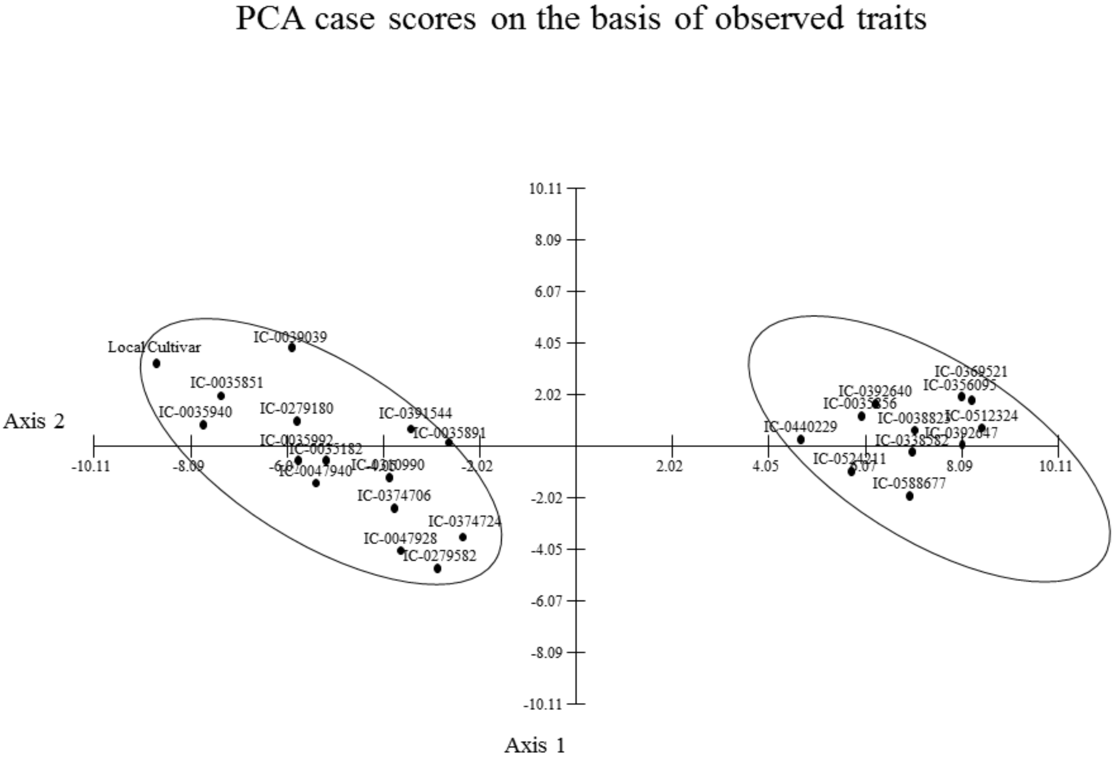
PCA case scores on the basis of observed traits

Figure 3.5: Principal Component analysis of morphological data with respect to 26 onion genotypes

The configuration of the twenty-six onion genotypes along with Local Cultivar are shown in Figure 3.5. The coordination of the genotypes on all the axes together revealed that genotypes IC-0512324, IC-0392647, IC-0392640, IC-0369521, IC-0356095, IC-0038823, IC-0035856, IC-0588677, IC-0524211 and IC-0338582 were the most distinct genotypes for the characters studied. It is customary to choose one variable from these identified groups. Thus for the first group average bulb weight is best choice, as this has the largest loading from component one, equatorial diameter for the second, and TSS for the third group (Table 3.15). The average bulb weight had discriminating ability to 10 genotypes from the 26. This suggests that our PCAs determine characters responsible for individual discrimination. Appropriate consideration should be given to characters which contributed positively to first three principal components while selecting the best genotypes.

3.4 Conclusion

The present investigation provides considerable information on performance, genetic diversity of evaluated genotypes and their interrelationship and correlation among the traits studied. Such information is prerequisite for selection of genotypes for cultivation as well as selection of parents for crop improvement programs. The maximum plant height and leaf length were observed in genotype IC-0391544 while maximum number of leaves, leaf width and chlorophyll content were observed in IC-0279582, IC-392640 and IC-0035940, respectively. While least days to maturity were observed in genotype IC-0374724. Least double/deformed bulbs and least neck thickness were observed in IC-0588677. Highest polar diameter and equatorial diameter were observed in IC-0338583 and IC-0047928, respectively. The genotype IC-0512324 showed highest TSS, dry matter, average bulb weight and bulb yield. All genotypes were grouped into two clusters and four sub clusters I, II, III, and IV. The maximum inter sub cluster diversity was observed among the genotypes grouped into sub clusters I and IV. Genotypes of sub clusters II, III and IV on basis cluster mean values deserve consideration for their direct use as parents in hybridization programs to develop high yielding onion varieties. Significant genetic variability among the tested genotypes was observed, which means there are good prospects of improvement through wide hybridization by crossing genotypes.

CHAPTER 4

COMPARATIVE PERFORMANCE OF ONION GENOTYPES USING 'SETS AND SEEDLINGS' AS PLANTING MATERIAL AT LEH COLD DESERT

Abstract

The present investigation was carried out to study the effect of two different planting materials (set and seedling) and genotypes on bulb yield, its quality and vegetative growth. The experimental material comprised of two planting material and ten genotypes. The experiments were conducted at Vegetable Research Unit of Defense Institute of High Altitude Research, DRDO, Leh during the cropping season 2013 and 2014 in Randomized Block Design with five replications. There was significant effect planting material and genotypes on all the studied parameters. Wall Brown genotype showed highest plant survival, chlorophyll content, days to maturity, polar diameter, equatorial diameter, average bulb weight and bulb yield when grown through set among all the genotypes. The highest plant height and number of leaves, leaf area, were obtained in the genotype Brown Spanish. The least neck thickness, highest TSS and dry matter were observed in the genotype Red Cereole. While lowest double/deformed bulbs were observed in the genotypes Lock Roy. The results indicated that all the genotypes under set planting performed better than seedling ones.

4.1 Introduction

Ladakh is the highest altitude plateau region in India (much of it being over 3000m) and is snow covered high passes restrict approach to entire region. The movement and transportation to the region remains halted during almost half of the year due heavy snowfall at the high altitude passes. Difficult geographical and climatic conditions altogether offer a tough life with scarce resources. Fragile ecological system and short cropping season (May to September) creates a big challenge to the agriculturists [16]. As mentioned earlier onion supply in the region often fall short to deployed armed forces and local population due to round the year consumption and non-significant contribution of local produce to meet the demand. There are many reasons for low local production but most significant are lack of recommended geographic specific better performing genotypes and short growing period for crops. Thus, there is an urgent need to work on both these aspect for increasing the indigenous production of onion in Ladakh

Onion is grown in winters in the rest of country so most of recommended high yielding onion varieties are short day plants. The crop is grown in summers at high altitude Ladakh, during which days are long. Due to ignorance and non-arability of long day specific varieties farmers are growing short day cultivars in Ladakh region. The cultivars of this group do not perform better in term of yield and quality of quality bulbs in long day conditions. We have already evaluated 25 hilly region specie genotypes of onion to solve this problem and recommend a few better performers. This investigation was designed to supplement such efforts in which 9 long day genotypes procured from Bejo Sheetal Seeds Maharashtra were evaluated for various quantitative and qualitative traits at DIHAR DRDO Leh.

Another major reason of low onion productivity and production in Ladakh is short crop growing season. Here the season cycle is just reverse of what is required. When grows as winter season crop, the season changes from winters to summers and require rising temperature for physiological maturity of the bulbs. However, crop is grown during summers in Ladakh and there is onset of winters in last phase of its growing period. This not only reduces the growing period of the crop, but also an obstacle in achievement of physiological maturity of the bulbs. As a result the crop yield and well as quality are adversely affected. The shelf life of the bulbs which do achieve physiological maturity is also poor.

It was envisaged that this constraint can be overcome to some extent by somehow reducing the crop duration by adopting a suitable production technology. The cultivation of onion *(Allium cepa*L) can be accomplished by three different methods like seed to bulb, seed to seedling to bulb and sets to bulb production. Direct sowing of seeds in the field, requires longest time (about 8 months) for the crop to mature. This method is labor-intensive, requires thinning, more number of weeding, hoeing, and irrigation for successful crop production, and such a long period is not available in Ladakh. In transplanting method 7–8 weeks old the seedlings, raised in nursery beds under protected or in open field conditions are transplanted in the field. Transplanting method reduces the cropping period by two months. In Ladakh, the seedlings are raised from mid-March to mid-May in protected conditions, and transplanted in the open field in the month of May. On an average, 40% seedlings die, from transplanting to establishment period and another 10% plants during the cropping period (ref if any). In the physiographic conditions of Ladakh, crops do not reach the full maturity stage owing to slow growth and the onset of winter by October, which results in a low yield with poor quality. This means that further reduction in cropping period is required to overcome such problems.

To achieve it, this part of research was designed test and compare ‘seedling’ and ‘sets’ as onion planting material in Ladakh region. Sets are tiny bulbs of onion, obtained when seedlings are allowed to grow for 90–100 days and bulbs attain diameter of about 1–2 cm. The literature on onion indicates that plants raised via sets as planting material, require shorter growing season. Brewster [28] described sets as small onion bulbs, ranging from 2-3 g in fresh weight, produced by growing a crop from seed at a high population density of 1000 to 2000 plants per m^2. Owing to their size, sets produce a more robust plant at emergence as compared to seedlings. This allows them to be grown successfully in less favorable growing conditions where the use of transplant and direct sowing are limited. Sets have a shorter growing season than plants from seeds and this advantage is often exploited when a rapid or early season production is required Sets are commercially used to produce early green onions, but they can also be used for dry bulb production. Larger sets tend to produce higher yield, and bulbs mature earlier than those produced from smaller sized sets. On the other hand, large size sets often produce splits and doubles and also are more likely to bolt [185],[30].

4.2 Materials and methods

The experiment was conducted during the month of May to October in the year 2013 and 2014 at Vegetable Research Unit of the Defence Institute of High Altitude Research, Leh-Ladakh, (altitude 3500 m above MSL, latitude 34°8'16.119" N, longitude 77°34'19.2216"E). The soil texture of the experimental site was silty loam with pH 7.1±0.2. Organic carbon and organic matter content were 1.2.±0.4% and 4.2±0.5%, respectively. The experimental material consisted of 10 genotypes of onion viz. Red Cereole, Katarina Red 3, Katarina Red 7, Supreme, Cyrus, Lock Roy, Legend, Wall Brown, Brown Spanish and a Local Cultivar having broad spectrum of variation, which were received from Bejo Sheetal Seeds. The experiment was laid down in Randomized block design (RBD) with five replications. The plot size for each treatment was 2m×1m. Sets and seedlings of all the genotypes selected were of uniform size based on visual observations and transplanted on flat bed system. The plating materials of uniform size were transplanted on flat beds in their respective plots with constant 20 cm inter-row distance, while the intra-row spacing was 10 cm (Figure 4.1). Well rotten farmyard manure (FYM) at the rate of 20 t ha^{-1} was incorporated to the soil 30 days before transplanting of seedlings and sets. The recommended dose of NPK fertilizes was applied at a ratio of 80-60-60 kg ha^{-1}. All the Phosphorous, Potash and half dose of Nitrogen was applied during transplanting. While the remaining half dose of Nitrogen was applied after 30 days of transplanting. All the cultural and management practices viz. irrigation, weeding, hoeing and sprays for insect pests and disease control etc. were carried out uniformly for all treatments. Observations were recorded from 10 randomly selected plants from each genotype in each replication for fourteen traits viz., Plant survival (%), Plant height (cm), Number of leaves per plant, Leaf area (cm^2), Chlorophyll content (cci), Neck thickness (cm), Total soluble solids (%), Dry matter (%), Polar diameter (cm), Equatorial diameter (cm), Bulb shape index, Average bulb weight (g) and Bulb yield (kg/plot). Data recorded over two years were pooled due to a non-significant heterogeneity test [19]. Means of all observations were calculated and subjected to SPSS

21 statistical software. Two way ANOVA with 2-sided Tukey's HSD at $p \leq 0.05$ was carried out.

Figure 4.1: Planting of onion crop through sets; 1-sets, 2, 3-planting of sets; 4-crop after 30 days of planting

4.3 Result and Discussion

The data pertaining to Plant survival, plant height and number of leaves of plant raised from ‘seedlings’ and ‘sets ‘are presented in table 4.1. The data indicates that plants raised via sets were highly superior to plants raised through seedlings among all the genotypes. Amongst the genotypes, maximum survival rate was observed for Wall Brown (64.20 %) followed by Supreme (61.70 %) and Katarina Red 7(61.45 %) when were grown through seedlings. While in those raised from the sets, the highest survival rate was observed for Wall Brown (98.15 %) followed by Lock Roy (98.00 %) and Supreme (97.65 %). There was marked difference in plant survival in plants raised through sets and seedlings in all the genotypes, maximum being in 98.20% vs 64.20% in case of Wall Brown. This result validate the hypothesis that problem of low survivability of onion seedlings after transplant at agro climatic condition of Ladakh can be solved by using ‘sets’ as planting material. The perusal of data (Table 4.1) indicated that the plant height in all the genotypes was significantly higher in the plants that were raised from the sets than those raised from the seedlings. Among all the genotypes raised from seedlings (Table 4.1), maximum plant height was observed for Brown Spanish (42.74 cm) followed by Red Cereole (38.46) and Supreme (37.29 cm) whereas in those raised from the sets, the maximum plant height was recorded for Brown Spanish (48.28 cm) followed by Red Cereole (41.12 cm) and Cyrus (39.61 cm). The plants raised from the Sets showed significantly higher number of leaves than those raised from the seedlings for all the genotypes (Table 4.1). Among plants raised from seedlings maximum number of leaves was observed for Brown Spanish (13.87) followed by Local Cultivar (11.02) and Supreme (9.25). The plants grown through sets showed the maximum number of leaves for the Genotype Brown Spanish (16.02) followed by Local Cultivar (11.74) and Supreme (9.56).

Table 4.1: Effect of sets and seedlings on Plant survival, Plant height and Number of leaves at agroclimatic condition of Leh

S.no.	Genotypes	Plant Survival (%)		Plant Height (cm)		Number of Leaves	
		Seedling	**Set**	**Seedling**	**Set**	**Seedling**	**Set**
1.	Red Cereole	57.70 ± 4.35^{abc}	97.55 ± 1.92^{d}	38.46 ± 2.76^{cd}	41.12 ± 2.64^{bc}	8.52 ± 1.42^{cd}	9.30 ± 1.16^{b}
2.	Katarina Red 3	56.25 ± 7.65^{abc}	93.80 ± 3.72^{d}	29.75 ± 3.50^{ab}	31.04 ± 3.62^{a}	4.92 ± 0.88^{a}	5.15 ± 0.53^{a}
3.	Katarina Red 7	61.45 ± 3.85^{cd}	97.60 ± 1.19^{b}	33.58 ± 3.03^{abc}	35.55 ± 2.57^{ab}	6.24 ± 0.66^{abc}	6.28 ± 0.94^{b}
4.	Supreme	61.70 ± 2.39^{cd}	97.65 ± 1.93^{b}	37.29 ± 2.01^{bcd}	38.95 ± 1.10^{ab}	9.25 ± 0.78^{de}	9.56 ± 0.65^{bc}
5.	Cyrus	52.30 ± 3.91^{b}	92.25 ± 2.63^{a}	36.65 ± 4.38^{abcd}	39.61 ± 4.71^{ab}	8.22 ± 1.62^{cd}	9.06 ± 0.78^{b}
6.	Lock Roy	60.75 ± 3.54^{cd}	98.00 ± 1.13^{b}	32.18 ± 1.93^{abc}	34.44 ± 1.26^{ab}	7.06 ± 0.71^{abcd}	7.39 ± 0.67^{ab}
7.	Legend	54.60 ± 2.97^{c}	97.30 ± 2.68^{b}	32.18 ± 1.34^{abc}	34.28 ± 1.02^{ab}	8.28 ± 2.06^{cd}	9.35 ± 2.55^{c}
8.	Wall Brown	**64.20 ± 1.92^{d}**	**98.15 ± 1.27^{b}**	33.27 ± 4.31^{abc}	35.39 ± 5.28^{ab}	5.84 ± 0.59^{b}	6.23 ± 0.90^{a}
9.	Brown Spanish	50.90 ± 3.31^{b}	94.80 ± 2.27^{a}	**42.74 ± 5.53^{d}**	**48.28 ± 8.55^{c}**	**13.87 ± 1.06^{f}**	**16.02 ± 0.98^{d}**
10.	Local Cultivar	61.35 ± 3.73^{cd}	94.45 ± 3.21^{ab}	28.93 ± 5.21^{a}	34.11 ± 3.40^{b}	11.02 ± 0.85^{e}	11.74 ± 1.00^{c}
	Mean	58.11 ± 5.63	96.16 ± 2.94	34.50 ± 5.25	37.28 ± 5.97	8.32 ± 2.74	9.01 ± 3.20

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

The data pertaining to the leaf area depicted that plants raised from the sets had significantly higher leaf area compared to those raised from the seedlings for all the genotypes (Table 4.2). Among the plants raised from seedlings, maximum leaf area was observed for Brown Spanish (129.89 cm^2) followed by Wall Brown (56.51 cm^2) and Cyrus (52.92 cm^2) while in those raised from the sets the maximum leaf area was observed for Brown Spanish (157.07 cm^2) followed by Wall Brown (65.53 cm^2) and Cyrus (61.26 cm^2). The observation of data (Table 4.2) revealed that among all the genotypes, maximum chlorophyll content was recorded for the genotype Wall Brown (39.86 cci) followed by Red Cereole (39.63 cci) and Cyrus (37.80 cci) when grown through seedling while in those raised from the sets the maximum chlorophyll content was recorded for Wall Brown (39.88 cci) followed by Red Cereole (39.79 cci) and Cyrus (39.27 cci).

The days to maturity was found to be significantly lower in the plants raised from the sets compared to those raised from the seedlings for all the genotypes (Table 4.2). The difference was highly significant. Least days to maturity was observed for Red cereole (169.10) followed by Katarina Red 3 (169.20) and Katarina Red 7 (171.40) for plants raised from seedlings whereas in those raised from the sets, least days to maturity was observed for Red cereole (131.10) followed by Katarina Red 3 (131.90) and Local Cultivar (132.40), where days to maturity decreased.

Occurrence of double/deformed bulbs in various genotypes was found to be significantly different from each other (Table 4.3). Minimum double/deformed bulbs were observed for Lock Roy (0.74 %) followed by Cyrus (0.86 %) and Supreme (1.13 %) for plants raised from seedlings. On the other hand, the plants that were raised from the sets, showed minimum double/deformed bulbs in the genotype Lock Roy (0.82) followed by Cyrus (0.84 %) and Supreme (1.26 %). In both the planting materials, least double /deformed bulbs were observed when onion grown through seedlings.

Table 4.2: Effect of sets and seedlings on Leaf area, Chlorophyll content and Days to maturity at agro climatic condition of Leh

S.no.	Genotypes	Leaf Area (cm^{2})		Chlorophyll content(cci)		Days to maturity	
		Seedling	**Set**	**Seedling**	**Set**	**Seedling**	**Set**
1.	Red cereole	47.94 ± 9.03^{b}	65.48 ± 9.39^{d}	39.63 ± 2.11^{ab}	39.79 ± 0.54^{bc}	**169.10 ± 1.08^{a}**	**131.50 ± 1.06^{b}**
2.	Katarina Red 3	23.33 ± 7.49^{a}	27.10 ± 8.35^{a}	33.24 ± 1.41^{a}	33.77 ± 0.89^{a}	169.20 ± 1.92^{a}	131.90 ± 1.08^{b}
3.	Katarina Red 7	41.91 ± 7.80^{b}	49.61 ± 7.71^{c}	32.43 ± 0.93^{a}	32.24 ± 0.98^{a}	171.40 ± 1.34^{b}	133.10 ± 1.29^{a}
4.	Supreme	46.79 ± 6.53^{b}	59.32 ± 6.21^{d}	35.24 ± 2.25^{ab}	39.30 ± 3.96^{bc}	173.80 ± 1.10^{b}	134.40 ± 1.02^{a}
5.	Cyrus	52.94 ± 8.79^{c}	61.26 ± 7.28^{d}	37.80 ± 5.82^{ab}	39.27 ± 2.69^{bc}	177.20 ± 1.30^{c}	135.75 ± 1.46^{ab}
6.	Lock Roy	35.09 ± 8.43^{ab}	40.60 ± 11.11^{ab}	34.31 ± 2.30^{a}	36.70 ± 3.37^{ab}	172.40 ± 0.82^{c}	135.10 ± 0.82^{b}
7.	Legend	38.86 ± 10.98^{ab}	43.93 ± 7.00^{ab}	36.60 ± 2.27^{ab}	37.75 ± 2.40^{ab}	177.00 ± 1.00^{c}	135.70 ± 11.39^{b}
8.	Wall Brown	56.51 ± 30.71^{b}	65.53 ± 10.04^{b}	**39.86 ± 2.04^{b}**	**39.88 ± 2.35^{bc}**	178.10 ± 0.55^{c}	137.60 ± 0.82^{ab}
9.	Brown Spanish	**129.89 ± 17.17^{d}**	**157.07 ± 23.57^{e}**	36.39 ± 1.88^{a}	38.24 ± 4.27^{ab}	176.70 ± 0.57^{c}	135.70 ± 0.82^{ab}
10.	Local Cultivar	35.04 ± 5.09^{a}	42.80 ± 5.15^{b}	34.84 ± 1.52^{ab}	35.76 ± 1.50^{ab}	172.80 ± 1.35^{b}	132.40 ± 0.42^{a}
	Mean	50.83 ± 31.02	61.22 ± 37.68	35.66 ± 3.13	37.82 ± 3.93	173.77 ± 3.37	134.96 ± 4.64

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

Minimum neck thickness was observed for the Red Creole (0.64 cm) followed by Wall Brown (0.71 cm) and Katarina Red 7 (0.77 cm) while among all the genotypes that were raised from the sets, minimum neck thickness was observed for Red Creole (0.61 cm) followed by Wall Brown (0.69 cm) and Katarina Red 7 (0.71). In case of the plants grown through the seedling, highest total soluble solid was observed for the Red Cereole (13.14 %) followed by Katarina Red 3 (12.53 %) and Katarina Red 7 (11.92 %). while in those raised from the sets, it was highest for Red Cereole (13.90 %) followed by Katarina Red 3 (13.69%) and Katarina Red 7 (13.28)(Table 4.3). Highest dry matter content was observed for Red Cereole (14.71 %) followed by Katarina Red 3 (14.18%) and Katarina Red 7 (13.59 %) in those which were grown through seedling (Table 4.4). While in those raised from the sets, significantly high dry matter content was observed for Red Cereole (15.50 %) followed by Katarina Red 3 (15.35 %) and Katarina Red 7 (14.89 %).There was a non-significant variation for dry matter content of bulbs between those grown from seedlings or sets.

Among all the genotypes, significantly higher polar diameter was observed for Wall Brown (7.01 cm) followed by Legend (6.74 cm) and Cyrus (6.62 cm) when grown through seedlings (Table 4.4). In those raised from the sets, significantly higher polar diameter was observed for Wall Brown (7.28 cm) followed by Legend (6.84 cm) and Brown Spanish (6.21 cm). The plants raised from sets registered significantly higher polar diameter than those raised from the seedlings. The plants raised from sets were observed to record significant maximum equatorial diameter than those raised from the seedlings (Table 4.4). Maximum equatorial diameter was observed for the Wall Brown (9.60 cm) followed by Lock Roy (6.59 cm) and Legend (6.53 cm)in the bulbs raised from seedlings, while in those raised from sets significant maximum equatorial diameter was observed for Wall Brown (9.96 cm) followed by Legend (7.63 cm) and Cyrus (7.35 cm). When planted from seedlings and sets, the plant arising from sets were highly superior to the plants raised from seedlings.

Table 4.3: Effect of sets and seedlings on Double/deformed bulb, Neck thickness and Total soluble solids.

S.no.		Double/deform bulb (%)		Neck Thickness(cm)		Total Soluble Solids (%)	
	Genotypes	Seedling	Set	Seedling	Set	Seedling	Set
1.	Red cereole	4.77±0.44^{b}	5.32±0.84^{b}	**0.64±0.08^{a}**	**0.61±0.06^{a}**	**13.14±0.85^{d}**	**13.90±0.58^{d}**
2.	Katarina Red 3	4.41±0.49^{b}	4.88±0.30^{b}	1.00±0.07^{a}	1.01±0.08^{b}	12.53±0.93^{cd}	13.69±0.42^{d}
3.	Katarina Red 7	1.96±1.27^{a}	2.26±0.91^{a}	0.77±0.06^{a}	0.71±0.04^{ab}	11.92±1.31^{cd}	13.28±1.18^{d}
4.	Supreme	1.13±0.72^{a}	1.26±0.56^{a}	0.81±0.14^{a}	0.72±0.14^{ab}	8.29±0.37^{b}	9.19±0.41^{b}
5.	Cyrus	0.86±0.30^{a}	0.84±0.32^{a}	0.90±0.27^{a}	0.78±0.25^{ab}	6.55±0.45^{ab}	7.16±0.57^{a}
6.	Lock Roy	**0.74±0.30^{a}**	**0.82±0.20^{a}**	0.98±0.15^{a}	0.79±0.13^{ab}	7.44±0.92^{ab}	7.83±0.78^{ab}
7.	Legend	1.34±0.52^{a}	1.60±0.63^{a}	0.96±0.12^{a}	0.93±0.13^{ab}	6.38±0.81^{ab}	7.14±0.80^{a}
8.	Wall Brown	8.43±1.52^{c}	10.15±1.53^{c}	0.71±0.04^{a}	0.69±0.05^{ab}	6.48±0.44^{a}	6.90±0.42^{a}
9.	Brown Spanish	11.21±1.19^{d}	13.18±1.95^{d}	2.56±0.37^{bc}	2.37±0.27^{c}	10.93±0.48^{c}	11.33±0.46^{c}
10.	Local Cultivar	98.90±1.14^{e}	99.44±0.47^{e}	3.06±0.68^{c}	3.16±0.29^{d}	6.90±1.07^{ab}	7.62±1.15^{a}
	Mean	13.38±29.01	13.98±29.07	1.24±0.85	1.18±0.84	9.09±2.71	9.79±2.90

Values represented as mean ± SE; for each column, different lowercase letters indicate significantly different at $p<0.05$, as measured by 2-sided Tukey’s HSD among genotypes. Bearing common superscript (abcd) within column does not vary significantly.

Table 4.4: Effect of sets and seedlings on Dry matter, Polar diameter and Equatorial diameter at agroclimatic condition of Leh

S. no.		**Dry matter (%)**		**Polar diameter (cm)**		**Equatorial Diameter (cm)**	
	Genotypes	**Seedling**	**Set**	**Seedling**	**Set**	**Seedling**	**Set**
1.	Red cereole	**14.71±0.76^{d}**	**15.50±0.72^{d}**	4.80±0.68^{ab}	5.03±0.53^{b}	6.12±0.31^{bc}	6.55±0.41^{bcd}
2.	Katarina Red 3	14.18±0.82^{cd}	15.35±0.35^{d}	4.65±0.43^{ab}	4.78±0.40^{ab}	4.14±0.80^{ab}	4.55±0.49^{ab}
3.	Katarina Red 7	13.59±1.22^{cd}	14.89±1.08^{d}	5.64±1.15^{bcd}	5.98±0.88^{bc}	5.02±0.31^{bc}	5.14±0.24^{abc}
4.	Supreme	9.87±0.55^{b}	10.82±0.45^{b}	5.86±0.50^{bcd}	5.84±0.63^{bc}	6.21±0.33^{bc}	6.45±0.60^{cd}
5.	Cyrus	8.20±0.20^{a}	8.83±0.51^{a}	6.62±0.99^{cd}	6.01±1.3^{b}	6.13±1.22^{c}	7.35±1.46^{d}
6.	Lock Roy	9.09±0.75^{ab}	9.47±0.64^{ab}	5.47±0.55^{b}	5.80±0.49^{c}	6.59±0.87^{c}	6.91±0.62^{cd}
7.	Legend	8.19±0.79^{ab}	8.48±1.04^{a}	6.74±0.74^{cd}	6.84±0.73^{c}	6.53±1.61^{c}	7.63±1.37^{d}
8.	Wall Brown	8.21±0.38^{ab}	8.55±0.34^{a}	**7.01±0.75^{d}**	**7.28±0.97^{d}**	**9.60±1.15^{d}**	**9.96±0.73^{d}**
9.	Brown Spanish	12.60±0.18^{c}	12.93±0.38^{c}	6.00±0.32^{bcd}	6.21±0.31^{bc}	5.78±0.81^{bc}	5.93±1.11^{bcd}
10.	Local Cultivar	8.50±1.31^{ab}	9.37±1.03^{ab}	3.66±0.51^{a}	4.04±0.50^{a}	3.58±0.55^{a}	3.82±0.44^{a}
	Mean	10.73±2.69	11.43±2.89	5.64±1.19	5.75±1.10	6.32±1.78	6.39±1.83

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

Amongst the genotypes (Table 4.5), maximum average bulb weight was observed for Wall Brown (152.61g) followed by Legend (138.36 g) and Cyrus (138.34 g) when grown from seedlings. While in those raised from the sets the highest average bulb weight was observed for Wall Brown (203.08 g) followed by Legend (194.12 g) and Cyrus (185.04 g). In all the genotypes the bulb yield was found to be significantly higher in the plants raised from the sets than those raised from the seedling (Table 4.5). Among plants raised from seedlings, maximum bulb yield was observed for Wall Brown (19.59 kg/plot) followed by Legend (15.10 kg/plot) and Cyrus (14.47 kg/plot). While in those raised from sets the maximum bulb yield was observed for Wall Brown (39.86 kg/plot) followed by Legend (37.77 kg/plot) and Cyrus (34.15 kg/plot). The plants raised from sets were observed to give highly significant maximum bulb yield than those raised from the seedlings.

To have an idea of performance of 10 genotypes with respect to 15 quantitative and qualitative traits top three performing genotypes are shown against each trait in table 4.6. From this analysis, it can be concluded that Wall Brown was best genotype that featured in 08 traits including average bulb weight and bulb yield as top three performers. Genotype Red Cereole, Cyrus and Legend were also good for many important traits. The three genotypes Wall Brown, Red Cereole and Brown Spanish can be directly recommended to cultivate in Ladakh or to be included in further breeding programme.

Table 4.5: Effect of sets and seedlings on Average bulb weight and Bulb yield at agro climatic condition of Leh

S. no.		**Average bulb weight (g)**		**Bulb yield (kg/ plot)**	
	Genotypes	**Seedling**	**Set**	**Seedling**	**Set**
1.	Red Cereole	100.56±5.48^{b}	107.37±9.30^{c}	11.62±1.22^{ab}	20.95±1.99^{c}
2.	Katarina Red 3	81.73±7.28^{a}	91.37±5.51^{b}	9.20±1.44^{a}	17.14±1.25^{c}
3.	Katarina Red 7	92.89±6.94^{ab}	107.32±6.76^{c}	11.40±1.28^{ab}	20.94±1.21^{c}
4.	Supreme	114.63±17.88^{c}	145.51±16.30^{d}	14.15±2.35^{c}	28.42±3.16^{d}
5.	Cyrus	138.34±12.86^{d}	185.04±11.24^{e}	14.47±1.16^{c}	34.15±1.23^{e}
6.	Lock Roy	103.11±13.17^{b}	145.57±13.59^{d}	12.56±1.93^{bc}	28.51±2.40^{d}
7.	Legend	138.36±4.29^{c}	194.12±10.12^{e}	15.10±0.60^{c}	37.77±2.24^{e}
8.	Wall Brown	**152.61±5.68^{e}**	**203.09±5.19^{fg}**	**19.59±0.85^{d}**	**39.86±2.42^{ef}**
9.	Brown Spanish	103.28±10.77^{b}	132.94±12.40^{d}	10.55±1.68^{ab}	25.22±2.52^{d}
10.	Local Cultivar	80.75±9.47^{a}	88.59±9.13^{a}	9.17±1.01^{a}	16.73±1.81^{b}
	Mean	109.53±24.55	140.09±41.74	12.73±3.17	26.96±8.09

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

The difference between the genotypes included in this study might be due to the differences in their genetic makeup as has been reported by Kandil et al. [83]. Similar results were obtained by Akhtar et al. [5], Gemma et al. [59].Soleymani and Shahrajabian[182] reported that foliage fresh weight, bulbing ratio, plant height, weight of bulb, total yield, favorite yield, total percentage of dry matter and nitrate content in bulb was significantly influenced by genotype.. The stimulatory effect of sets on all the quantitative and qualitative traits could have been due to presence of more sprouting initials and reserved food material thereby resulting in better establishment and survival of plants. Similar finding was reported [93], [79].

Table 4.6: Trait wise three topmost performing genotypes (based on set data)

S.no.	Traits	PS	PH	NL	CC	MD	D/DB	NT	TSS	DM	PD	ED	ABW	BY	Total
1	Red Cereole		**		**	**		***	***	***					06
2	Katarina Red 3					**			**	**					03
3	Katarina Red 7							*	*	*					03
4	Supreme	*	*				*								03
5	Cyrus			*	*		**					*	*	*	06
6	Lock Roy	**					***								02
7	Legend										**	**	**	**	04
8	Wall Brown	***		**	***			**			***	***	***	***	08
9	Brown Spanish		***	***							*				03
. 10	Local Cultivar														00

*****highest value; **second highest; *third highest. PS-Plant survival; PH-Plant height; NL-Number of leaf; CC-Chlorophyll content; MD-Maturity days; D/DB-Double/deformed bulb; NT-Neck thickness; TSS-Total soluble solids; DM-Dry matter; PD-Polar diameter; ED-Equatorial diameter; ABW-Average bulb weight; BY-Bulb yield.**

Conclusion

Sets as planting material proved to be better as compared to seedling as all the genotypes performed better with respect to quantitative and qualitative traits when plants were raised through sets. The survival percentage of plants of all the genotypes was better when sets were used as planting material, and there was a wide difference in average survival percentage of plants when sets and seedlings were used as planting material. The average number of days for crop maturity for all the genotypes was 134.31 days and 173.77 days when sets and seedlings were used as planting material respectively;where days to maturity decreased. So crop could be harvested on an average 39.46 days earlier compared to conventional method. Amongst the genotypes, set raised plant of Wall Brown followed by Legend and Cyrus gave highest bulb weight and bulb yield, which are important yield parameters.

CHAPTER 5

EVALUATION OF DIFFERENT ONION GENOTYPES FOR MINERAL CONTENT AS MEASURED BY ICP-OES AT AGROCLIMATIC CONDITION OF LEH, TRANS-HIMALAYA, INDIA

Abstract

The present investigation was conducted on ten genotypes of onion at the Vegetable Research Unit of Defence Institute of High Altitude Research during the year 2014. The objective of this study was to evaluate the variability of mineral accumulation of in onion genotypes revealed by multivariate analysis for use in further breeding programs to achieve improved cultivars, targeting high nutrient concentrations. A total of 10 mineral elements and 10 onion genotypes were investigated, and considerable variation was observed in most of the genotypes. The highest concentrations of Ca, Mg, P, Zn and Cu were observed in Cyrus, Supreme, Legend, Brown Spanish, and Lock Roy, respectively. On the other hand, the highest concentrations of Fe, Na and Mn were observed in the Local Cultivar, while the highest K and B contents were observed in Red Cereole. All genotypes were grouped into three different clusters. The highest inter cluster distance was observed between II and III and lowest between I and II. Cluster means of cluster II for the content of Ca, P, Na, Zn and Cu were highest. Whereas Cluster means of cluster I for content of Mg, K and B were highest amongst three clusters. Parent should be selected accordingly in breeding programs for mineral content improvement in future. The principal component analysis explained that 99.67% of total variation accounted for first three PCs of the variance among 10 genotypes. Onion genotypes were classified into three groups and outcomes of the experiments revealed that the first three principal components were highly effective in classifying the examined genotypes on the basis of mineral accumulations. Significant differences exhibited in mineral concentrations among the examined onion genotypes allow direct selection of those genotypes with higher elemental concentration.

5.1 Introduction

The high altitude trans-Himalayan cold desert is characterized by adverse climatic conditions, which are unfavorable for human survival. There is sufficient evidence that in this unfavorable environment, sustained energy deficit, malnutrition, vitamin and mineral deficiency, and metabolic disorders could occur due to changes in physiological functions [163], Hota et al. [77]. Malnutrition, elemental nutrition and vitamin deficiency in high altitude cold deserts could also result due to less availability of fresh fruit and vegetable during most part of the year. This problem can be alleviated either by increasing the availability of such commodities and or by improving the nutritional composition of food resources routinely consumed by people. Thus, researchers have been interested in improving the nutritional quality of plants, with respect to both nutrient composition and concentration [26].

The *Alliaceae* family plays an important role in the human diet. Onion is consumed round the year by all sections of people throughout the year, so could be good means of fighting elemental deficiencies especially in Ladakh region where availability and consumption of other vegetables is scarce. The elemental composition of the edible parts of some *Allium* species has been used to define their geographical origin Ariyama et al. [12], [13]; Ariyama et al. [11]. In addition, the analysis of 63 major and trace elements enabled the differentiation between conventionally and organically grown onions Gunderson et al. [71]. However, apart from these studies and a few others (Alvarez et al.[9],Galdon et al. [58], Edet et al. [51], Ogbonna et al. [134] there has been limited research on the elemental composition of bulb onions. Most of the work on the manipulation of mineral nutrients in onions has focused on the effects on qualitative parameters, particularly the effects on pungency (enzymatically produced pyruvate after maceration), flavor precursors, and firmness.

Therefore, it is prudent to identify onion germplasm with high levels of the mineral nutrients for direct recommendation of high mineral genotypes and inclusion of such genotypes in future breeding programs. Assessment of genetic relatedness with respect to mineral compositional and multivariate analysis methods could be useful tools for selecting a suitable genotype Santos et al. [159]. No studies have been performed for the analysis of mineral content in onion under the agroclimatic conditions of Ladakh. The aim of the research presented here was to determine the mineral content of bulbs of different long-day onion genotypes grown in the agroclimatic conditions of Ladakh, and to describe genotypic differences in the mineral content of onion bulbs by using multivariate analysis.

5.2 Materials and methods

5.2.1 Experimental Site

The field experiment was conducted at the vegetable research unit (altitude 3500 m above MSL, latitude 34°8'16.119" N, longitude 77°34'19.2216"E), DIHAR, DRDO, Leh-Ladakh, India. The experimental site had silty loam soil having pH 7.1±0.2, 1.2.±0.4%, organic carbon content and 4.2±0.5% organic matter.

5.2.2 Experimental Material

To determine the genetic variation of mineral accumulation, 10 genotypes of onion (*Allium cepa* L.) were selected, of which 9 had been obtained from Bejo Sheetal Seeds and one genotype (Local cultivar) from Leh. Sets were planted on 7th May, 2014 in the experimental plots.

5.2.3 Experimental design

Randomized block design with four replications was used to conduct experiments. The plot size was kept at 2.0 m^2 and the row and plant spacing were kept 20 and 10 cm, respectively. All recommended agronomic practices and plant protection measures were followed uniformly for all the genotypes. The harvesting was carried out in the first week of September. The onion bulbs were harvested and collected in 25 kg plastic nets and dried in ambient conditions for five weeks as per standard practice in India. Roots and dry aerial parts of plants were removed. The damaged and or diseased bulbs were discarded.

5.2.4 Sample preparation

The samples were taken randomly. Samples from each genotype in each replication were taken from three bulbs. The dry outer skins of bulbs were removed, and a vertical piece of tissue was taken from the basal end of the bulb. Each sample was weighed and immediately snap-frozen in liquid nitrogen, and stored at -40 ºC until it was lyophilized. Samples were lyophilized and stored before mineral analysis. Dry weight measurements were made using lyophilized samples.

5.2.5 Digestion of Samples

1 g fine powder of onion bulb was taken in a 30 mL glazed porcelain crucible. The crucible was placed in a cool muffle furnace and muffled at 500 °C for 2 h. These were was then removed from the furnace, cooled and 3.0 mL HNO_3 was added to it. The samples were heated on a hot plate at 100 °C until dried. The crucible was again placed in the muffle furnace, allowed to cool, and 10 mL HCL was added to it. The samples were transferred to a 50-ml volumetric flask, diluted with deionized water and mixed thoroughly. All the elements

were analyzed by using the Inductively Coupled Atomic Adsorption Spectrometer (Perkin-Elmer, Optima 7000 DV), 104 according to the methods in the Handbook of Reference Methods for Plant Analysis [82] and instruction given by supplier of ICP OES. Each sample was analyzed in triplicate and elements quantified were P, Na, Ca, K, Fe, Cu, B, Zn, Mn and Mg.

5.2.6 Statistical analysis

Genetic diversity was evlated using [108] generalized distance (D^2) extended [148]. Tocher's Method was used to cluster genotypes on basis of mineral content. The intra-cluster distances were calculated by using formula given by Singh et al 1985 [174]. The principal component analysis was used reveal principal components contributing in varaibilty, which were chosen on basis of screen test [99]. Agglomerative Hierarchical cluster analysis was used to establish differences and similarities among the genotypes. Gower General Similarity Coefficient used as distance measure the parameter. It best reflects the differences among the genotypes [88]. All statistical analyses were carried out based on 10 mineral element using SPSS 21.

5.3.1 Result and Discussion

It was observed that all the genotypes showed significant variation in mineral accumulation. The onion genotypes were found to be rich in Calcium, ranging from 38.21 to 133.70 mg/l (Table 5.1). The highest Calcium content (133.70 mg/l) was observed for the genotype Cyrus, followed by Legend (130.00 mg/l) and Local cultivar (129.70 mg/l). The Iron content ranged from 1.10 to 3.84 mg/l as shown in the Table 5.1. The highest loading of Iron was observed for the genotype Local Cultivar (3.67 mg/l), followed by Katarina Red 7 (3.21 mg/l) and Lock Roy (2.54). The Magnesium content ranged from 85.38 to 105.06 mg/l as shown in Table 5.1. Maximum Magnesium content was observed in the genotype Supreme (105.06 mg/l) followed by Red Cereole (102.13 mg/l) and Cyrus (98.52 mg/l). The Phosphorus content ranged from 66.52 to 163.5 mg/l as shown in Table 5.1. The highest loading for Phosphorus was observed for the genotype Legend (163.40 mg/l) followed by Wall Brown (159.30 mg/l) and Local cultivar (158.30 mg/l). The Potassium content ranged from 122.4 to 274.60 mg/l (Table 5.1). The highest Potassium content was observed in Red Cereole (274.60 mg/l), followed by Supreme (254.00 mg/l) and Legend (224.30 mg/l). Sodium content ranged from 20.50 to 57.61 mg/l (Table 5.1). The maximum Sodium loading was observed in the genotype Local Cultivar (57.61 mg/l), followed by Wall Brown (50.27 mg/l) and Brown Spanish (48.70 mg/l). The Zinc content ranged from 1.44 to 4.02 mg/l (Table 5.1). The maximum Zinc content was observed in the genotype Brown Spanish (4.02 mg/l), followed by Local Cultivar (3.91 mg/l) and Wall brown (3.24 mg/l). The Manganese content was ranging from 1.10-2.20 mg/l (Table 5.1). The highest Manganese content was observed in genotype Local Cultivar (2.20 mg/l) followed by Brown Spanish (2.11 mg/l) and Supreme (1.77 mg/l). The Copper content was ranging from 0.55-0.88 mg/l (Table 5.1). The highest Copper content was observed in genotype Lock Roy (0.88 mg/l) followed by Local Cultivar (0.73 mg/l) and Brown Spanish (0.70 mg/l). The Boron content was ranging from 0.33-1.64 mg/l (Table 5.1). The maximum Boron content was estimated in genotype Red Cereole (1.64 mg/l) followed by Cyrus (0.77 mg/l) and Katarina Red 7 (0.67 mg/l). On the basis of result it can be concluded that high loading of minerals may be due to high uptake rate of a particular genotype of specific minerals in order to synthesize plant secondary metabolite increase their survival. The difference between studied genotypes might be related to genetic potential of different genotypes.

Table 5.1: Variability in ten onion genotypes for mineral content (mg/L)

S. no.	Genotypes	Calcium	Iron	Magnesium	Phosphorus	Potassium
1	Red Cereole	100.40±5.13^{c}	1.16±0.08^{a}	102.13±2.00^{ef}	66.52±2.94^{a}	**274.60±10.89^{g}**
2	Katarina Red 3	85.80±4.72^{b}	1.78±0.08^{c}	95.05±3.48^{cd}	77.83±2.94^{b}	186.70±8.46^{bc}
3	Katarina Red 7	38.21±1.01^{a}	3.21±0.03^{g}	91.17±3.53^{bc}	148.60±2.94^{e}	122.40±1.75^{a}
4	Supreme	85.55±2.07^{b}	1.79±0.06^{c}	**105.06±1.89^{f}**	128.90±2.07^{d}	254.00±10.89^{f}
5	Cyrus	**133.70±1.01^{f}**	1.33±0.02^{b}	98.52±0.68^{de}	94.83±2.94^{c}	135.50±2.04^{a}
6	Lock Roy	95.47±2.23^{c}	2.54±0.02^{f}	87.51±0.77^{ab}	123.93±1.60^{d}	177.30±6.73^{b}
7	Legend	130.00±2.23^{f}	2.23±0.02^{e}	90.18±1.11^{abc}	**163.50±2.47^{g}**	224.30±3.14^{e}
8	Wall Brown	116.56±1.94^{e}	2.45±0.02^{f}	88.74±1.43^{ab}	159.30±3.19^{fg}	202.51±7.84^{cd}
9	Brown Spanish	110.65±1.98^{d}	2.09±0.07^{d}	85.38±4.51^{a}	153.60±2.94^{ef}	176.90±5.90^{b}
10	Local Cultivar	129.70±1.07^{f}	**3.67±0.14^{h}**	90.30±0.72^{abc}	158.30±2.94^{fg}	208.50±10.89^{de}
11	Range	38.21-133.70	1.16-3.67	85.38-105.06	66.52-163.50	122.40-274.60
12	Total	102.60±27.75	2.22±0.75	93.40±6.64	127.53±34.57	196.27±46.17

Table 5.1: Conti…

S. no.	Genotypes	Sodium	Zinc	Manganese	Copper	Boron
1	Red Cereole	20.50±1.73^{a}	1.44±0.19^{a}	1.16±0.08^{a}	0.66±0.05^{cd}	**1.64±0.05^{f}**
2	Katarina Red 3	23.06±2.40^{a}	2.00±0.08^{c}	1.66±0.09^{b}	0.62±0.03^{bc}	0.63±0.09^{d}
3	Katarina Red 7	31.47±2.64^{b}	1.70±0.04^{b}	1.70±0.05^{b}	0.55±0.03^{a}	0.67±0.02^{d}
4	Supreme	37.68±1.05^{c}	1.50±0.06^{ab}	1.77±0.02^{b}	0.60±0.01^{ab}	0.60±0.03^{d}
5	Cyrus	42.40±2.64^{cd}	2.67±0.02^{e}	1.10±0.01^{a}	0.63±0.03^{bc}	0.77±0.03^{e}
6	Lock Roy	46.00±3.54^{de}	2.45±0.18^{de}	1.14±0.02^{a}	**0.88±0.02^{f}**	0.47±0.01^{bc}
7	Legend	45.42±3.54^{de}	2.25±0.03^{d}	1.13±0.02^{a}	0.63±0.02^{bc}	0.33±0.^{03a}
8	Wall Brown	50.27±2.80^{e}	3.24±0.08^{f}	1.20±0.01^{a}	0.63±0.03^{bc}	0.49±0.02^{c}
9	Brown Spanish	48.70±1.90^{e}	**4.02±0.19^{g}**	2.11±0.10^{c}	0.70±0.01^{de}	0.43±0.01^{bc}
10	Local Cultivar	**57.61±3.54^{f}**	3.91±0.07^{g}	**2.20±0.06^{c}**	0.73±0.03^{e}	0.39±0.02^{ab}
11	Range	20.50-57.61	1.44-4.02	1.10-2.20	0.55-0.88	0.33-1.64
12	Total	40.31±11.80	2.52±0.91	1.52±0.41	0.66±0.09	0.64±0.36

Values represented as mean ± SD; in each column, values having different superscripts are significantly different at $p<0.05$, as measured by 2-sided Tukey's HSD among genotypes. There is no significant difference among values bearing common superscript within column.

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5.3.2 Cluster Analysis

Based on the D^2-value estimates of genetic divergence, the 10 onion genotypes were grouped into three distinct clusters (Table 5.2). A wide range of diversity was observed in the experimental material for the majority of the characters studied. Cluster I consisted 4 genotypes (40 %), Cluster II consisted of a maximum of 5 genotypes (50 %), and cluster III consisted of 1 genotype (10 %) (Table 5.2).

Table 5.2: Clustering pattern of ten onion genotypes based on Mahalanobis' D^2 values

S.no.	Clusters	Genotypes	Contribution (%)
1	I	Katrina Red 7, Katrina Red-3, Supreme, Cyrus	40
2	II	Lock Roy, Legend, Wall Brown, Brown Spanish, Local Cultivar	50
3	III	Red Cereole	10

Cluster II had the highest intra-cluster distance (2.322) indicating the high divergence among the genotypes of all the clusters, while considering the inter-cluster distance, a minimum distance (3.892) was noticed between I and II (Table 5.3). Maximum inter cluster distance (4.371) was noticed between II and III followed by distance (4.352) between I and III (Table 5.3).

Table 5.3: Average intra- (bold face) and inter-cluster distance (D^2) of 10 onion genotypes

S.no.	Clusters	I	II	III
1	I	**2.050**		
2	II	3.892	**2 .322**	
3	III	4.352	4.371	**0.000**

According to Ghaderi et al. [60], increasing parental distance implies a great number of contrasting alleles at the desired loci, and to the extent that these loci recombine in the F2 and F3 generation following a cross of distantly related parents, the greater will be the opportunities for the effective selection for yield factors. Thus, the crossing of genotypes from these clusters with other clusters may produce a higher degree of heterotic expressions in the first filial generations (F1) and a wide range of variability in subsequent segregating (F2) populations. The distribution of genotypes into different clusters showed no uniformity with respect to their origin, ruling out the association between geographical distribution and genetic divergence. Similar results have been reported in onion Lee et al. [104], [127], Khar et al. [92].

The mean values of 10 different mineral elements in three clusters are shown in table 5.4. The mean value of mineral elements viz. Calcium, Phosphorus, Sodium, Zink and Copper content were highest for cluster II among three clusters. Crosses involving parents belonging to more divergent clusters would be expected to manifest maximum heterosis and a wide variability in their genetic architecture [176].

Table 5.4: Mean values for three clusters based on ten mineral elements

S.no.	Minerals	Clusters		
		I	II	III
1	Calcium	101.36	**116.48**	38.21
2	Iron	1.52	2.59	**3.21**
3	Magnesium	**100.19**	88.42	91.17
4	Phosphorus	92.02	**151.73**	148.60
5	Potassium	**212.70**	197.90	122.40
6	Sodium	30.91	**49.60**	31.47
7	Zinc	1.91	**3.17**	1.70
8	Manganese	1.42	1.56	1.70
9	Copper	0.63	**0.71**	0.55
10	Boron	**0.91**	0.42	0.67

In the present study, Cluster II was more divergent than the others. The selection of parents should also consider the special advantage of each cluster and each genotype within a cluster, depending on the specific objective of hybridization [36]. Thus, crosses involving Cluster II with any other cluster are expected to exhibit high heterosis, and could result in segregates with higher mineral content.

A dendrogram was drawn to display the biochemical relationship among different long-day genotypes of onion on the Gover general Similarity Coefficient from the biochemical data matrix. All genotypes were represented in three clusters (Figure-5.1). The dendrogram based on UPGMA method analysis grouped the genotype into population groups with main clusters I, II, and III. Cluster I represents the genotypes Katrina Red 7, Katrina Red-3, Supreme, and Cyrus, while cluster II represents the genotypes Lock Roy, Legend, Wall Brown, Brown Spanish, Local Cultivar, and cluster III represents Red Cereole. Results of PCA were comparable with the cluster analysis.

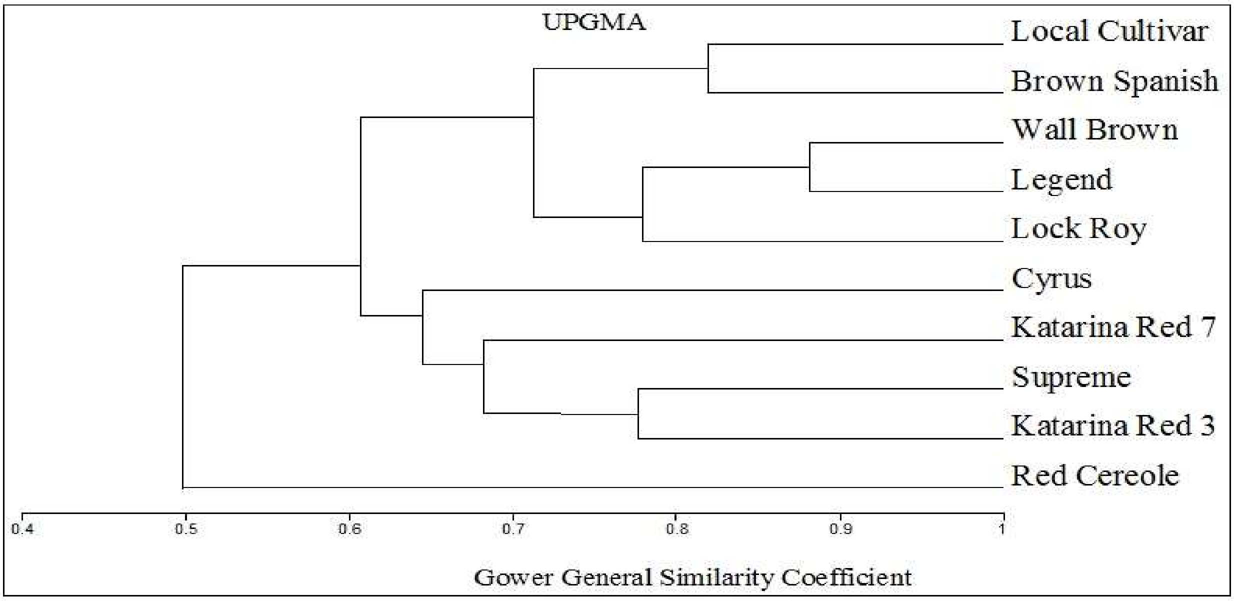


Figure 5.1: Genetic relationship among ten genotypes of onionbased on mineral elements

Principal component analysis (PCA) reflects the importance of the largest contributor to the total variation at each axis of differentiation [168]. The eigen values are often used to determine how many factors to retain. The sum of the eigen values is usually equal to the number of variables. The coefficients defining the eleven principal components of these data are given in Table 5.5. The coefficients are scaled, so that they present correlations between observed variables and derived components. Three principal components, PC1 to PC3, which are extracted from the original data, account for nearly 99.212% of the total variation suggesting that these principal component scores might be used to summarize the original 10 variables in any further analysis of the data. Out of the total principal components retained, PC1, PC2, and PC 3 with values of 52.95, 30.75 and 15.51%, respectively, contributed more to the total variation.

Table 5.5: Eigen values proportion of variability and minerals contributed to the first three PC's of onion genotypes

	PC 1	**PC 2**	**PC 3**
Eigenvalues	2427.85	1409.745	711.35
Percentage	52.951	30.746	15.514
Cum. Percentage	52.951	83.697	99.212
	PCA variable loadings		
Variables	PC 1	PC 2	PC 3
Calcium	0.172	0.386	0.879
Iron	-0.007	0.011	-0.011
Magnesium	0.073	-0.09	-0.008
Phosphorus	-0.257	0.854	-0.382
Potassium	0.946	0.188	-0.254
Sodium	-0.064	0.278	0.125
Zinc	-0.006	0.016	0.015
Manganese	-0.001	0.003	-0.004
Copper	0	0	0.001
Boron	0.004	-0.007	0

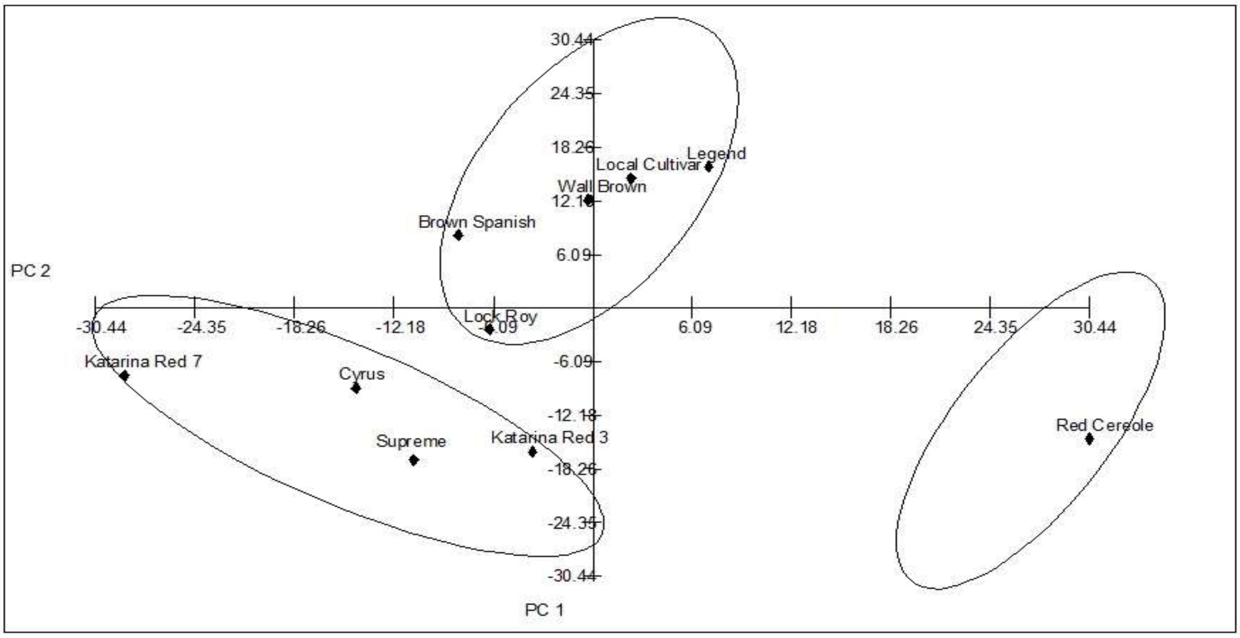


Figure 5.2: Principal Component Analysis of mineral element with respect to genotypes of onion

According to Chahal and Gosal [36], characters with largest absolute values closer to unity within the first principal component influence the clustering more than those with lower absolute values closer to zero. Therefore, in the present study, differentiation of the accessions into different clusters was because of the relatively high contribution of a few characters rather than a small contribution from each character. Accordingly, the first principal component had a high positive component loading from K (0.946), Ca (0.172), and a high negative loading from P (-0.257), while the remaining traits in PC1 did not contribute; rather their effects were distributed among other PCs. The traits, which contributed more positively to PC3, were Ca (0.879), Na (0.125), average bulb weight, and TSS (Table 5.5). PC2 had a high positive component loading from P (0.854), Ca (0.386), Na (0.278), and K (0.188), and a high negative loading from Mg (-0.09).The positive and negative loading shows the presence of positive and negative correlation trends between the components and the variables. Therefore, the above mentioned characters, which loaded high positively or negatively, contributed more to the diversity and were the ones that were most differentiated (Figure 5.2).

5.4 Conclusion

Significant genetic variability were observed in genotypes with respect to mineral content that provides an excellent opportunity of improvement through hybridization by crossing genotypes in different clusters. Highest calcium content was observed in the genotype Cyrus whereas highest Iron and Sodium in Local Cultivar. Highest magnesium content was observed in genotype Supreme while phosphorus in Legend. Whereas highest Potassium and boron content was observed in Red Cereole. Highest Zinc content was observed in Brown Spanish and the highest copper content in Lock Roy. Genotypes under study were divided in three clusters and it is recommended on the basis of inter cluster genetic distance and intra cluster genetic distance to use genotypes from cluster II and III as parents in further breeding programs.

CHAPTER 6

EVALUATION OF ONION GENOTYPES FOR QUALITY OF BULB DURING POSTHARVEST STORAGE IN AGRO-CLIMATIC CONDITIONS OF LADAKH

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, 150 days in controlled atmosphere 2±1ºC and 75±1% Relative humidity. The experiment was laid in randomized block design with three replications. The observations viz. dry matter, TSS, hardiness of bulb, total sugar, non-reducing sugar and reducing sugar loss in weight (%), Rotting (%) Sprouting (%), Sprout length (cm), Incident of black mold (%), 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), incident of black mold increased gradually during storage. While hardiness/firmness of bulb, ascorbic acid, reducing sugar, physiological losses in weight, marketable bulbs were decreased gradually during storage period. Similar pattern of increase and decrease of all the observed traits were shown by all the genotypes. On the other hand, at genotypic level, significant variation was observed for their storage potential. Genotypes Red Cereole, Katarina Red 3 and Katarina Red 7 were found to be superior with repect to many of the post-harvest traits and most importantly gave highest marketable bulb at the end of storage. So 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 altitude. So it is recommended to cultivate these if objective is to store onion to extend availability in temperate regions.

6.1 Introduction

Marketability, appearance and nutritional composition of onion are greatly affected by the shelf life of variety, storage time, storage facilities and conditions. Shelf life of onion is of more relevance in India, because it is produced in the production hot spots states of Maharashtra, Gujarat, and Karnataka and transported to long distance markets. The problem is more aggravated in India due to poor postharvest management, absence of adequate cold storage or preservation facilities, and poor transport infrastructure. India is second largest producer and exporter of onion worldwide but due to constraints mentioned above post harvest losses may be up to 66% [1], [3], [120], [122] resulting in poor quality and shortage of onion in relation to the requirement.

Sprouting of onion during storage occurs due to increase in respiration rate that generate heat, result in moisture loss from bulb and thus decreases its shelf life [190]. It is suggested that the storage life of onion is greatly affected by cultivar, storage regime, and temperature, which are directly related to sprouting process [98].

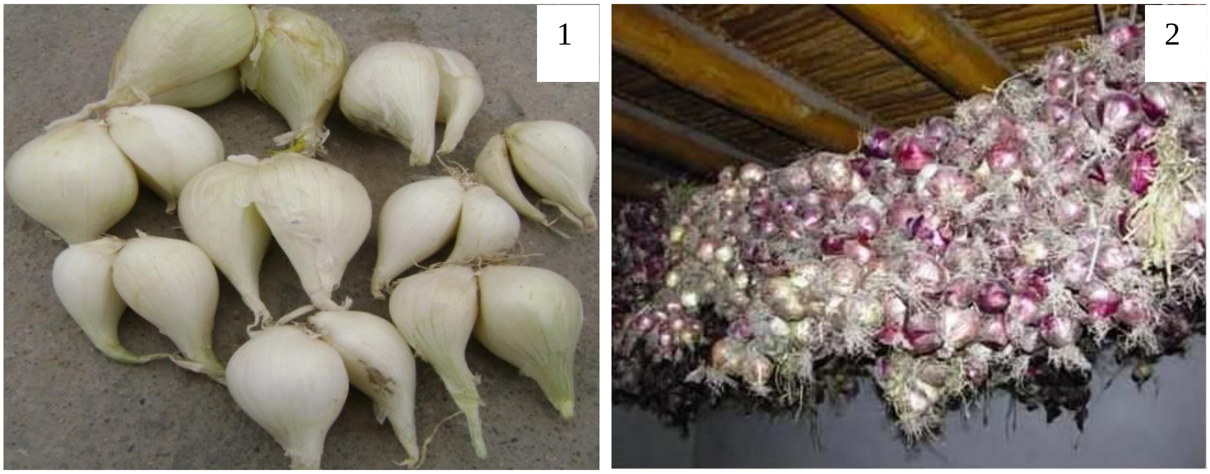


Figure 6.1: 1-local cultivar; 2-traditional method of onion storage.

Onions are produced in the cool-dry season and are kept in stores to ensure availability throughout the year. India produces surplus quantity of onion and the growers store their produce in fields temporarily. Rooms, shelters, sheds, under ambient conditions [3] are generally used for storage under which postharvest rots and deterioration in quality occurs rapidly [122]. Farmers store onions using traditional techniques in shelters at ambient temperatures (Figure 6.1), probably due to lack of cold storage [188]. The traditional storage methods cause sprouting in onion bulbs, resulting in increased postharvest loss of the produce.

The rotting, sprouting and physiological weight loss [23] and postharvest diseases [56] are reasons for huge post-harvest losses reduction in marketable quality. According to Gubb and MacTavish [70], moisture loss from onion bulb is greater at a room temperature more than 27˚C. Several studies have been carried out regarding onion storage at various temperatures and it was found that refrigeration temperature lowers respiration rate and inhibits sprouting and decay, which helps retain the quality along with increasing the shelf life of onion [48]. Hot and humid storage conditions are suitable for the growth of black mold (*Aspergillus niger*) [187], [208], [209], bacterial soft rot (*Pseudomonas gladioli*) [200], [205], and other storage diseases in the onion bulb. Rotting and re-growth increase the rate of respiration, heat generation, and consequently enhance moisture loss and reduce the shelf life, which are the major factors causing the deterioration in onion bulbs during storage [190]. The quality of onion bulbs is better retained at low temperature (0 °C).

Many physiological changes take place during the post-harvest storage and result in decline of the quality of the produce. There are two types of patterns for the changing sugar content in onion bulbs during storage. Firstly, the sugar content changes with storage period following a regular trend, which may be monotonous increase, decrease, or a stable pattern. Secondly, there may be sharp fluctuations in the concentration, with the amplitude and period of fluctuations showing no specific behavior [169]. Sugar content in onion during storage greatly depends on the type of cultivar, storage temperature, and postharvest treatments and techniques showing either a constant or a fluctuating behavior. Hence, there are conflicting reports in literature and findings [39], [74]. The ascorbic acid content in onion differs from species to species and cultivar to cultivar. Ascorbate oxidase is a copper-containing enzyme that oxidizes ascorbic acid to dehydroascorbic acid (DHA) in the presence of molecular oxygen [154].Ascorbate oxidase is associated with rapidly growing regions in the plant and occurs bound to cell walls as well as a soluble protein in the cytosol. Under stress, such as pathogen or chemical exposure, ascorbate oxidase levels increase [105]. Thus, ascorbic acid is found to decrease throughout the storage period.

The studies indicate that postharvest losses can be minimized not only by postharvest management, but also by preharvest management such as the use of improved varieties and proper cultural practices. There are some cultivars that cannot maintain their quality for a long duration at ambient temperatures; however there are some cultivars that can be stored for more than six months under ambient conditions without deterioration in quality. Kariuki and Kimani [84] suggested that the selection of such long storing cultivars could help in maintaining and enhancing the physico-chemical characters of onion bulbs. Although several studies regarding shelf life of onion have been carried out, there is no research work on the storage behavior of long-day onion cultivated in Leh-Ladakh. This motivated researchers to conduct experiments for shelf life study in long-day onion genotypes. This research work was undertaken to understand the physico-chemical changes occurring during storage of onion bulbs under controlled climatic conditions of Leh-Ladakh with main objective to elucidate the storage behavior of different long-day onion genotypes.

6.2 Materials and method

The present study was conducted during two consecutive cropping seasons (2013 and 2014) at the vegetable research unit of Defence Institute of High Altitude Research, Defence 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 amsl in Leh-Ladakh (Jammu & Kashmir), India. Climate of the area is typically dry temperate with extreme fluctuations in the temperature, and precipitation is negligible.

The seeds were sown in trenches with 5 cm spacing between lines during the first week of April 2013. At that time, all standard agronomic practices recommended for onion was carried out. After 60 days, when the seedlings reached optimum set/baby bulb size, they were harvested and cured in shade for one month. They were stored at 2±1 ^{0}C and 75±2 % relative humidity in an onion store. The experimental material consisted of nine long-day genotypes and one local cultivar of onion, viz., Red Creole, Katarina Red 3, Katarina Red 7, Supreme, Cyrus, Lock Roy, Legend, Wall Brown, Brown Spanish, Local Cultivar and Nasik Red. Sets were planted on 18th April 2013 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 prior to storage and 5 kg healthy bulbs from each treatment were packed in thin gunny bags and kept in the storage for storage studies (Figure 6.2). Bulbs were stored under controlled atmosphere (CA) conditions (2±1ºC and 75±1% relative humidity).

Figure 6.2: Storage of onion

6.2.1 Experimental design

The experiment was conducted in randomized block design with three replications. The observations were recorded at 50, 100, and 150 days of storage for the traits, such as Physiological loss in weight (%), Rotting (%), Sprouting (%), Sprout length (cm), Incidence of black mold (%), and Marketable bulbs (%).

6.2.2 Dry matter (%)

Bulbs were randomly selected from each treatment and cut into small pieces with the help of stainless steel knife. A known weight of the sample was dried in hot air oven at 60 °C till a constant weight was obtained. The percent dry matter was calculated by the following formula.

$$\text{Dry matter percent} = \frac{\text{Dry weight of sample}}{\text{Fresh weight of sample}} \times 100$$

6.2.3 Total Soluble Solids (%)

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

6.2.4 Hardness of the bulb (kg/cm^2)

The hardness of 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/cm^2.

6.2.5 Ascorbic Acid (mg/100 g)

The vitamin C (Ascorbic acid) in the onion bulb was calculated with the titrimetric method [10]. 100 g of fresh onion bulb were taken and crushed the whole material into pestle and mortar by adding 100 ml 2 per cent oxalic acid solution. The whole content was finally transferred into a preweighed beaker and the weight of crushed slurry was recorded on digital balance. Twenty gram crushed slurry was transferred into 100 ml capacity of conical flask and volume was made 100ml by adding one per cent oxalic acid solution. The content of the conical flask was filtered with the help of filter paper and filtrate was collected into another flask. 5ml filtrate of each flask was taken and titrated the whole content of conical flask against dye solution (2, 6-dichloro phenol endophenol) until the end point (pink colour) was achieved and titer value was noted. 5ml standard ascorbic acid solution was taken in another conical flask and titrated the whole content against dye solution until the end point was obtained. The results were expressed as mg of ascorbic acid per 100g of fresh sample.

6.2.6 Total Sugars (%)

Total sugar was measured by using the phenol-sulphuric acid method [50]. This is a rapid and reproducible procedure for the estimation of simple sugars and their derivatives which utilizes phenol as the specific organic color-developing agent. In addition to simplicity and sensitivity, this method offers the advantage that it is largely unaffected by the presence of proteins. As a consequence, it provides a useful technique for estimating the carbohydrate content of glycoproteins. Simple sugars, oligosaccharides, polysaccharides, and their derivatives, including the methyl ethers with free or potentially free reducing groups, give an orange yellow color when treated with phenol and concentrated sulfuric acid. The method of phenol-sulphuric acid reaction can be used for the quantitative colorimetric micro-determination of sugars and their methyl derivatives, oligosaccharides and polysaccharides. The reaction is sensitive and the color is stable.

6.2.6.1 Reagents

1. Conc. H_2SO_4
2. Phenol, 80% (Add 20g of distilled water to 80g of phenol). The resulting water-clear solution is stable for months at room temperature. A pale yellow colour develops slowly upon standing but does not interfere with the assay.
3. Stock solution of D-Glucose: (10mg/100ml or 0.01g/100L): dissolve 1g glucose and make volume to 100ml. Take 1ml of this and dilute to 100m and use as stock (100µg/ml).

6.2.6.2 Procedure

A) **For Sample:** To 0.1ml of sample, add water to make volume to 2ml.Add 0.05ml phenol reagent followed by rapid addition of 5ml sulfuric Acid. Keep at room temperature for 30 minutes ad read optical density at 490 nm against reagent blank.

B) Plot standard curve using aqueous stock solution containing 10-120 µg of D-glucose (Table 6.1): Make dilutions of glucose standards with concentrations of 10, 20, 40, 60, 80, 100 and 120 µl/ml by transferring respective amount of glucose (i.e. 0.1ml to 1.2ml from glucose stock) prepared from the standard glucose solution (1mg/ml) and adjusting it to a total volume of 2 ml by adding distilled water as mentioned in Table6.1. . Add 5ml phenol reagent followed by rapid addition of 5ml sulfuric acid. Keep on room temperature for 30 minutes. Absorbance was taken at 490 nm.

Table 6.1: Preparation of standard curve

Glucose Stock Solution (ml)	Distilled Water (ml)	Concentration of Glucose Solution (µl/ml)
0.0	0.0	0
0.1	1.9	10
0.2	1.8	20
0.4	1.6	40
0.6	1.4	60
0.8	1.2	80
1.0	1.0	100
1.2	0.8	120

6.2.7 Estimation of Reducing Sugars

Sugars with reducing property (arising out of the presence of a potential aldehyde or keto group) are called reducing sugars. Some of the reducing sugars are glucose, galactose, lactose and maltose.

Reducing sugar (%) was determined as per the Dinitrosalicylic acid method [123]. Several reagents have been employed which assay sugars by using their reducing properties. One such compound is 3, 5-dinitrosalicylic acid (DNSA), in which alkaline solution is reduced to 3-amino-5-nitrosalicylic acid.

6.2.7.1 Reagents

1. DNSA reagent

Mix:

i)	Distilled water	1416 ml
ii)	3,5- Dinitrosalicylic acid	10.6g
iii)	Sodium hydroxide	19.8g

Dissolve above, and then add:

i)	Rochelle salts (Na-K tartarate)	306g
ii)	Phenol (melt at 50°C)	7.6m/
iii)	Sodium metabisulphite	8.3g

2. A sample (3 ml) was titrated with 0.1 N HCl using phenolphathalein as indicator. This
3. should take 5-6 ml HCl, added sodium hydroxide (NaOH) if required (2g= 1ml of 0.1N HCl).
4. Glucose standards: 0.2-5.0 mg of glucose per ml or per 0.5ml, as appropriate was used.
5. Glucose stock solution used: 500mg/100ml distilled water.

6.2.7.2 Procedure

A.) 1 g of sample was taken and crushed properly in mortar and pestle. It was transferred to test tube and the volume was made up to 1 ml with distilled water; add 3ml DNSA reagent and place in boiling water bath cool for 5 minutes to room temperature, dilute to make up the volume to 20 ml (necessary to get percent between 20% and 80%)

B.) Glucose Stock Solutions: Make dilutions of glucose standards with concentrations of 0.25, 0.5, 1.0, 2.0, 3.0, 4.0 and 6.0 mg/ ml by transferring (0.05ml, 0.1 ml, 0.2 ml, 0.4ml, 0.6 ml, 0.8ml, 1.0 ml of amount of glucose respectively from the standard glucose solution and adjusting it to a total volume of 1 ml by adding distilled water as mentioned in table 6.2. Each test tube was added with distilled water to make up the volume as 1 ml. Then, 3ml DNSA reagent was added and placed in boiling water bath, cooled for 5 minutes to room temperature, diluted to make up the volume to 20 ml (necessary to get percent between 20% and 80%).

C.) The absorbance (Optical Density, O.D.) was recorded at 540nm against blank reagent when the stability of colour developed till a period of 72 hours.

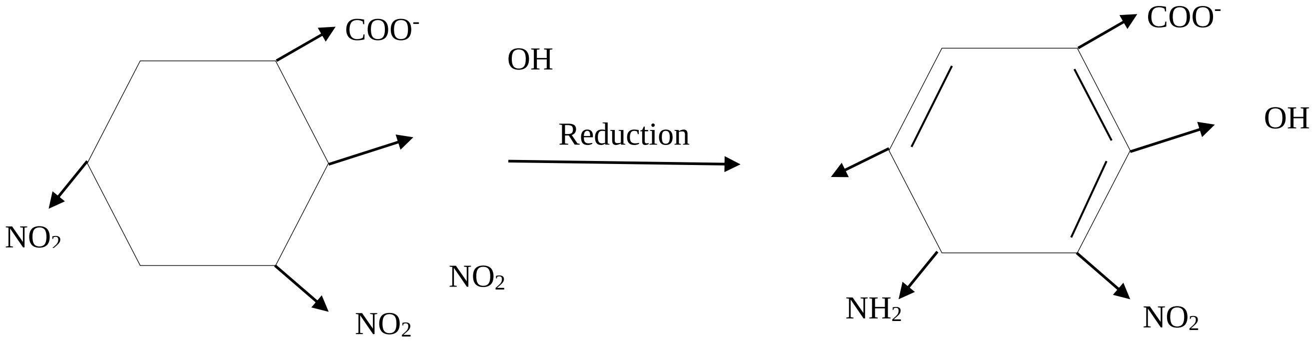
6.2.7.3 Standard curve

This should give a straight line intersecting abscissa at 0.04 mg of glucose. The 0.04 mg represents the glucose lost by oxidation. For accurate determination of low concentration of glucose 0.1 mg of glucose to each sample can be added. 3 ml of DNSA reagent reacts with about 10 mg of glucose. Therefore concentrated sugar solutions should be diluted so that samples for analysis will contain 5mg of reducing sugar or less [61].

Table 6.2: Standard curve for reducing sugars

Glucose Stock solution volume (ml)	Distilled water (ml)	Concentration of glucose solution (μl/ml)
0.0	1.0	0.0
0.05	0.95	0.25
0.1	0.9	0.50
0.2	0.8	1.0
0.4	0.6	2.0
0.6	0.4	3.0
0.8	0.2	4.0
1.0	0.00	6.0

$$\text{Reducing sugars (g/100g)} = \frac{\text{Abs}_{\text{sample}} \times \text{cocencentration of Standard} \times \text{dilution factor} \times 100}{\text{Abs}_{\text{standard}} \times \text{aliquot taken} \times 1000}$$



3, 5- dinitrosalicylic acid (DNSA)
(Yellow coloured complex)

Alkaline solution dinitrosalicylic acid method

3-amino-5-nitrosalicylic acid(Orange red coloured complex)

6.2.8 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 the same with 0.95 as given below [183].

$$\text{Nonreducing sugar (\%)} = (\text{Total sugar} - \text{reducing sugar}) \times 0.95$$

6.2.9 Weight Loss (%)

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

$$\text{Weight loss (\%)} = \frac{(\text{W0} - \text{W1} - \text{W2} - \text{W3})}{\text{W0}} \times 100$$

Where,

W0- initial weight of bulbs

W1- weight loss at 50 days of storage

W2- weight loss at 100 days of storage

W3- weight loss at 150 days of storage

6.2.10 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 by using the formula.

$$\text{Rotting (\%)} = \frac{\text{Weight of rotted bulbs}}{\text{Initial weight of the bulbs}} \times 100$$

6.2.11 Sprouting (%)

For determining 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 indicated the weight of the bulbs sprouted at 50, 100, and 150 DOS was calculated.

$$\text{Sprouting percentage} = \frac{\text{Weight of sprouted bulbs}}{\text{Initial weight of the bulbs}} \times 100$$

6.2.12 Sprout length (cm)

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

6.2.13 Incidence of black mold (%)

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

6.2.14 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 by using the following formula.

$$\text{Marketable bulbs (\%)} = \frac{\text{Weight of the healthy bulbs obtained}}{\text{Initial weight of the bulbs stored}} \times 100$$

6.2.15 Statistical Analysis

All statistical analysis in this research were carried out 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 5% significance level.

6.3 Results and Discussion

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% during 0, 50, 100, and 150 days of storage of onion bulbs (Table 6.3). The highest dry matter content was found in the genotype Red Creole, which ranged from 14.83% to 15.89%

during storage, followed by Katarina Red 3 (13.31% to 14.42% dry matter content during the storage period). The highest dry matter content (15.89%) was found at 150 days of storage of onion bulbs whereas minimum (8.03%) was found in Wall Brown at 0 days of storage. There was significant difference found in the dry matter content during storage. The increase in dry matter content during storage could be assumed to be due to the decrease in moisture content of the bulbs and increase in chemical constituents, in turn resulting in more dry matter [22]. Similar findings were reported by Kahsay et al.[81], the stored onions and shallots are characterized by high dry matter content. Among cultivars of bulb onions, dry matter content consisting mostly of fiber and sugars is an important quality factor determining bulb use; such high-dry-matter onions are required for dehydration. Similar findings were reported [57].

Table 6.3: Effect of different storage durations on dry matter content

S.no.		**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 represented as mean ± SE; for each column, different lowercase letters indicate significantly different at $p<0.05$, as measured by 2-sided Tukey's HSD among genotypes. Values bearing common superscript (abcd) within column do not vary significantly.

The T.S.S. 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 storage, 6.93% to 14.46, and 7.71% to 14.79% at 150 days of storage (Table 6.4). The T.S.S. was found have maximum values of 13.58%, 14.21%, 14.46%, and 14.79% at 0, 50, 100, and 150 days of storage in the genotype Red Creole, followed by Katarina Red 3 11.30%, 11.88, 12.04, and 13.37%. Among all the genotypes, the highest T.S.S was found at 150 days of storage. A significant difference was observed in all the genotypes during the storage period. The TSS was significantly influenced by different storage durations. Among the various storage durations tested, the maximum TSS was recorded at 150 days of storage, which was on par with the others. The higher percent TSS may be due to more loss of moisture and increase in dry matter content of the bulb, which leads to increase in the TSS content. These results are in close conformity with the findings [155], [138]. The least TSS was observed in bulbs at 0 days of storage. This may be due to lack of metabolic reactions in freshly harvested bulbs and high amount of moisture content in the bulb. Similar results were also observed [172], [130] in Sapota. According to Pak et al. [135], fructans are hydrolyzed to fructose during the storage period and results in higher TSS.

Table 6.4: 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 represented as mean ± SE; for each column, different lowercase letters indicate significantly different at $p<0.05$, as measured by 2-sided Tukey's HSD among genotypes. Values bearing common superscript (abcd) within column do not vary significantly.

The hardiness of onion bulbs of different genotypes varied from 5.77 Kg/cm^2 to 11.61 Kg/cm^2,5.11 Kg/cm^2 to 11.53 Kg/cm^2 , 4.23 Kg/cm^2 to 11.41 Kg/cm^2, and 3.48 Kg/cm^2 to 9.94 Kg/cm^2 during 0, 50, 100, and 150 days of storage, respectively (Table 6.5). The maximum hardiness of the bulb were recorded as 11.61 kg/cm^2, 11.53 kg/cm^2, 11.41 and 9.94 kg/cm^2 during 0, 50, 100, and 150 days of storage, respectively in the genotype Red Creole followed by Katarina Red 3 (11.09 kg/cm^2, 10.75 kg/cm^2, 10.01 kg/cm^2, and 9.13 kg/cm^2) at 0, 50, 100, and 150 days of storage, respectively. The hardiness of the bulbs decreased significantly during storage. Highest hardiness of the bulb was observed in fresh onion (11.61 Kg/cm^2 in Red Creole) and lowest hardiness of the bulb was observed at 150 days of storage (3.48 Kg/cm^2 in genotype Local cultivar). According to the findings of Darbyshire and Henry [46], 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 reduce the marketable bulbs. Similar findings were reported by [153], who classified the 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. Likewise, Suzuki and Cutliffe [186] stated that higher dry matter content resulted in firmer bulbs.

Table 6.5: 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 represented as mean ± SE; for each column, different lowercase letters indicate significantly different at $p<0.05$, as measured by 2-sided Tukey's HSD among genotypes. Values bearing common superscript (abcd) within column do not vary significantly.

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 6.6). 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 onion bulb decreased significantly during storage. It was found to be maximum in fresh onion. There is gradual decrease in the ascorbic acid content with the increase in the storage duration. This may be due to oxidative destruction of ascorbic acid in the presence of molecular oxygen by ascorbic acid oxidase enzyme. Similar results were reported [109].

Table 6.6: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 represented as mean ± SE; for each column, different lowercase letters indicate significantly different at $p<0.05$, as measured by 2-sided Tukey's HSD among genotypes. Values bearing common superscript (abcd) within column do not vary significantly.

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% during 0, 50, 100, and 150 days of storage of onion bulbs (Table 6.7). The highest total sugar content was found in the genotype Red Creole (8.90%) followed by Katarina Red 7 (8.72%) and Katarina Red 3 (8.46%) at 150 days of storage, whereas the minimum (4.98%, 5.11%, 5.29% and 5.98%) in the genotype Nasik Red at 0,50,100 and 150 days of storage, respectively. The total sugar content increased significantly during storage of onion bulbs in all the 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% during 0, 50, 100, and 150 days of storage of onion bulb, respectively (Table 6.8). The maximum reducing sugar content (4.92%, 4.84%, 4.56%, and 3.98%) at fresh, 50, 100, 150 days of storage, respectively, was found in the genotype Red Creole, 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 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.

Table 6.7: 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 represented as mean ± SE; for each column, different lowercase letters indicate significantly different at $p<0.05$, as measured by 2-sided Tukey’s HSD among genotypes. Values bearing common superscript (abcd) within column do not vary significantly.

Table 6.8: Effect of different storage durations on reducing sugar

S.no.		Reducing sugar (%)			
	Genotypes	**0 DOS (control)**	**50 DOS**	**100 DOS**	**150 DOS**
1.	Red Cereole	**4.92±0.01^{p}**	**4.84±0.02^{op}**	**4.56±0.08^{mno}**	**3.98±0.04^{jk}**
2.	Katarina Red 3	4.71±0.05^{nop}	4.63±0.06^{mnop}	4.33±0.07^{mno}	3.89±0.08^{jk}
3.	Katarina Red 7	4.77±0.08^{op}	4.67±0.10^{mnop}	4.38±0.02^{lmn}	3.95±0.06^{jk}
4.	Supreme	4.36±0.11^{lm}	4.17±0.09^{kl}	3.89±0.10^{jk}	3.47±0.14^{fghi}
5.	Cyrus	4.00±0.05^{jk}	3.83±0.05^{ijk}	3.50±0.03^{fghi}	2.97±0.04^{bc}
6.	Lock Roy	3.89±0.18^{jk}	3.72±0.14^{hij}	3.47±0.19^{efgh}	2.96±0.14^{bc}
7.	Legend	3.68±0.05^{hij}	3.55±0.06^{ghi}	3.25±0.02^{cdefg}	2.70±0.04^{ab}
8.	Wall Brown	4.77±0.05^{op}	4.63±0.06^{mnop}	4.34±0.06^{lm}	3.13±0.45^{cde}
9.	Brown Spanish	3.38±0.03^{defgh}	3.29±0.03^{cdefg}	3.11±0.01^{cd}	2.59±0.09^{a}
10.	Local Cultivar	3.52±0.14^{fghi}	3.40±0.15^{defgh}	3.19±0.10^{cdefg}	2.65±0.13^{ab}
11.	Nasik Red	3.32±0.09^{defg}	3.16±0.05^{cdef}	2.97±0.10^{bc}	2.56±0.13^{a}
	Range	3.32-4.92	3.16-4.84	2.97-4.56	2.56-3.98

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

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% during 0, 50, 100, and 150 days of storage, respectively (Table 6.9). 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 at 150 days of storage of onion bulbs. The increase observed in total sugars content could be due to the enzymatic hydrolysis of fructans to fructose and glucose during the storage period [171]. All genotypes showed a decreasing trend for reducing sugars during all storage durations. The differences among the varieties and storage durations were found to be significant. The decreasing trend may be due to the conversion of reducing sugar to starch during the storage period. Kukanoor [101] concluded that the reducing sugar content decreased during storage at low temperature. Similar findings were reported by Bogevska et al. [25]. The reducing sugar percentage monotonously reduced with time at 1 °C but varied at 4 °C and 21 °C [78]. Chope et al., [39] reported that the cultivar, postharvest treatments, and temperature can affect sugar content during storage, showing either a constant or an unstable pattern. Sharma & Lee [170] reported that sugar content could be correlated with other physiological factors such as dormancy break and sprouting. According to Sharma et al. [169], there are two types of sugar content behavior. According to the first one, the concentration of sugar changes with storage time following a regular pattern, such as a monotonous increase, decrease, or a stable behavior. Another type of behavior consists of strong fluctuations in the sugar content, with the amplitude and period of fluctuations showing no regular pattern.

Table 6.9: Effect of different storage durations on non-reducing sugar

S.no.		**Non-reducing sugar (%)**			
	Genotypes	**0 DOS (control)**	**50 DOS**	**100 DOS**	**150 DOS**
1.	Red Cereole	3.13±0.16^{ghijklmn}	3.41±0.14^{ghijklmno}	3.87±0.25^{lmnopq}	4.92±0.06^{tu}
2.	Katarina Red 3	2.65±0.16^{cdefghi}	2.86±0.16^{defghijk}	3.20±0.10^{efghijkl}	4.57±0.12^{qrst}
3.	Katarina Red 7	2.82±0.28^{defghij}	3.11±0.29^{fghijklm}	3.80±0.14^{opqrs}	4.83±0.12^{t}
4.	Supreme	3.12±0.20^{ghijklm}	3.21±0.15^{ijklmno}	3.86±0.23^{mnopqr}	4.63±0.03^{rst}
5.	Cyrus	2.56±0.39^{bcdefgh}	2.86±0.31^{defghijk}	3.52±0.25^{jklmno}	4.68±0.13st
6.	Lock Roy	**3.63±0.54^{jklmnop}**	**3.93±0.50^{nopqrs}**	**4.32±0.56^{pqrst}**	**5.62±0.27^{u}**
7.	Legend	2.29±0.14^{abcde}	2.64±0.11^{cdefghi}	3.66±0.10^{klmnop}	4.63±0.10^{rst}
8.	Wall Brown	2.54±0.21^{bcdefg}	2.86±0.23^{defghijk}	3.36±0.30^{hijklmno}	4.97±0.63^{tu}
9.	Brown Spanish	3.33±0.41^{ghijklmno}	3.58±0.36^{jklmnop}	3.97±0.42^{mnopqr}	4.98±0.36^{tu}
10.	Local Cultivar	1.87±0.19^{ab}	2.16±0.21^{abcd}	2.66±0.17^{cdefghi}	3.61±0.31^{jklmnop}
11.	Nasik Red	1.66±0.15^{a}	1.95±0.10^{abc}	2.32±0.13^{abcdef}	3.37±0.23^{ijklmno}
	Range	1.66-3.63	1.95-3.93	2.32-4.32	3.37-5.62

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

The physiological loss in weight in different genotypes of onion bulb 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 6.10). The physiological loss in fresh onion bulbs is considered 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. Lowest physiological loss in weight (2.99%, 3.94%, and 8.65%) at 50, 100, and 150 days of storage was found in the genotype Red Creole. Physiological loss in weight in all the genotypes increased significantly during the storage period. It was found to be least 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 [202] and hence depends on temperature. Therefore, the weight loss decreases significantly with storage at low temperature [97], [100]. The minimum weight loss under zero-energy cool chamber was probably due to less transpiration and respiration due to low temperature and high relative humidity [85] in potato. ‘Bombay Red’ and ‘Melkam’ varieties showed significantly higher percent of bulb weight loss [81]. In agreement with this finding, Msika and Jackson [129] described cultivar-specific weight losses of between 2 and 5% per month in warm ambient storage conditions in Zimbabwe. They indicated that the loss increment occurred from the second week to the end of the third month of the storage time. They described the relatively low initial rate to loss of water through the skin and by low level of respiration of dormant bulbs that was followed by a change to a steeper slope, indicating more rapid weight loss, due to high respiration rate and senescence of older fleshy scales. The higher weight loss at wider and closest intra-row spacing might be probably because wide planting distance produced large bulbs, the large bulb has highest water content and more surface area per unit of the bulb and then per kg, and thereby highest rate of transpiration. Mar [110] reported that the size, color, flavour, and storage quality of onions could be determined by the genotype. Rajkumar [147] indicated that the decline in weight was related with the continuation of higher incidence of sprouting, rotting, and percentage of diameter loss most likely through rise in the degree of respiration.

Table 6.10: Effect of different storage durations on weight loss

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

Table 6.11: 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 represented as mean ± SE; for each column, different lowercase letters indicate significantly different at $p<0.05$, as measured by 2-sided Tukey's HSD among genotypes. Values bearing common superscript (abcd) within column do not vary significantly.

The observation of data shows that the sprouting percent 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 6.11). 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. [62], the increasing trend in sprouting percent for different storage durations might be due to the increasing rate of respiration and metabolic processes. Similar findings were reported [48].

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 6.11). The sprouting length was found to be minimum (0.33, 0.33 and 1.21cm) in Red Creole, followed by Katarina Red 3 (0.30, 0.47 and 1.28cm), whereas maximum sprouting length (2.72, 5.82, and 9.00cm) was found during 50,100, and 150 days of storage, respectively in the local cultivar. Sprouting was found to be augmented among all samples through the length of the storage period in all the genotypes. Vintila et al. [194] perceived that sprouting was common to all genotypes of onion stored for different periods. Kukanoor [101] reported that sprouting triggered shrivelling of bulbs, which resulted in loss of marketable quality.

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 6.12). The lowest percentage incidence of black mold 0.67%, 0.82%, and 1.80% at 50, 100, and150 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 maximum 3.43, 12.58 and 15.48% at 50, 100, and 150 days of storage) in the local cultivar. In fresh onion bulbs, the percentage incidence of black mold was found to be minimum in all the genotypes, which significantly increased at 150 days of storage.

Table 6.12: Effect of different storage durations on Incidence of black mold

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

The rotting percent 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% during 50, 100, and 150 days of storage, respectively (Table 10). The minimum rotting percent of the bulb was recorded in Red Creole 0.66%,0.84%, and 2.58% at 50, 100, and 150 days of storage, respectively, followed by Katarina Red 3 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. On the other hand, the maximum rotting percent of the bulb was found to be in the local cultivar (6.92%, 13.45%, and 30.44% at 50, 100, and 150 days of storage). The rotting percent increased significantly during 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 congenial 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 that was responsible for the rotting of bulbs in storage was identified as black mold rot, caused by *Aspergillus niger*. It is interesting to note that rotting and black mold was very low at 50 days of storage. The rotting and black mold percent of bulbs significantly increased during 100 and 150 days of storage. The higher rotting and black mold percent may be due to the buildup of respiratory heat and humidity within the onion pile creating favourable conditions for the proliferation of the spoilage pathogens [38]. Storage life could also be associated with dry matter (DM) content. This result is in accordance with the report of Rafika et al. [144], who observed that DM was negatively correlated with the level of rotten bulbs. The marketable bulb percentage of different genotypes of onion was 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 6.12). The maximum marketable bulb percentage (97.01%, 96.06, and 88.77%) at 50, 100, and 150 days of storage, respectively, was found in the genotype Red Cereole. On the other hand, the minimum marketable bulb percentage content 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. It might be due to the genetic potential of these genotypes which produces high amount of TSS and Dry matter content that minimizes weight loss, sprouting percent, incidence of black mold during storage [144].

6.4 Conclusion

Different physiological and biochemical changes occur during the storage period in all the genotypes, which cause significant postharvest 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 durations. Highest dry matter and total soluble solids were observed in genotype red cereole which increases with the increase of days of storage whereas, ascorbic acid was found to be highest in Local cultivar. Total sugar and reducing sugar were found to be highest in Red Cereole which decreases with the increase in days of storage. Least weight loss, rotting, incidence of black mold, sprouting was observed in Red Cereole and highest marketable bulb yield was observed in Red Cereole. Therefore, among all the studied genotypes, Red Creole, Katarina Red 3, and Katarina Red 7 were characterized as having longer storage life with the highest proportion of marketable bulbs.

CHAPTER 7

SUMMARY

Farming at high altitude is a challenging task owing to the geography and extreme climatic conditions. The commercial high yielding crop varieties / genotypes do not perform same under such extreme conditions and often efforts are required to test their performance before recommendation. Even the routine production methods of crops are also need to be modulated and adjusted for optimum production. Onion is an important food crop grown and consumed almost all over the world and often fall short for huge Indian army deployed in the Leh- Ladakh region and local population due to negligible amount of local production. The present investigation was done with a main objective to figure out suitable onion genotypes / cultivars for optimum production in Ladakh, a high altitude, mountainous, cold desert region of India. At the Same time the genetic relationship among the genotypes based on many qualitative and quantitative traits were worked out which would be very helpful for breeders for planning onion breeding programs for improvement of traits in future. The comparative performance onion germplasm using 'Sets' and 'Seedlings' as planting material was also investigated to recommend suitable planting method and genotypes for optimum production in this region. In India 22% of onion produce is lost during postharvest storage and handling. Post-harvest losses of perishable produce are also a challenge in the extreme climatic condition of Ladakh. Available literature indicates that storage life of onion is also affected by cultivar / genotype Therefore, the main objective of this part of study was to elucidate the storage behaviour of different long-day onion genotypes.

In the present work, the variability, interrelationship, and divergence pattern of twenty six accessions of onion at high altitude were studied based on quantitative and qualitative traits. The genotypes IC-0392647, IC-0512324 and IC-0392640 were outperformers with respect to one or a few economically important traits among the evaluated genotypes and there for can be directly recommended for cultivation. There was significant genetic variability among the tested genotypes that provides an excellent opportunity to bring about improvement through wide hybridization by crossing genotypes in different clusters. On the basis Mahalanobis D^2-values twenty six onion accessions grouped in two clusters and four subclusters.

It was observed that the 'sets' was better planting material as all the genotypes performed better with respect to all the quantitative and qualitative traits when planted via sets compared to seedlings. Amongst the genotypes 'Wall Brown' followed by 'Legend' and 'Cyrus' gave highest bulb yield raised when raised through sets. Therefore the above three genotypes may be recommended for the cultivation through sets for high bulb yield in climatic conditions of Ladakh.

10 mineral elements in 10 onion genotypes were investigated and considerable variation was observed in most of the concentrations. Onion genotypes were classified into three groups. Genotypes grouped into Cluster II and III showed the maximum inter-cluster diversity. From the results it can be concluded that genotypes from cluster I for Mg, K and B, genotypes from cluster II for Ca, P, Na, Zn and Cu and genotypes of cluster III for Fe and Mn should be selected as parents for future hybridization program to improve the respective mineral content.

Onion bulbs of eleven genotypes including a Local cultivar and a national check were stored for 50, 100, 150 days in controlled atmosphere 2±1ºC and 75±1% relative humidity. The observations viz. dry matter, TSS, hardiness of bulb, total sugar, reducing sugar and non-reducing sugar, loss in weight (%), rotting (%) sprouting (%), sprout length (cm), incident of black mold (%),marketable bulbs (%) were recorded throughout the storage. Significant variation was observed for their storage potential of the genotypes under investigation and was concluded that the quality of the stored material depends on the genetic potential of the studied genotypes and storage durations. Among all the studied genotypes, Red Creole, Katarina Red 3, and Katarina Red 7 were characterized as having longer storage life with the highest proportion of marketable bulbs.

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10. **Jagdish Singh Arya,** Preeti, Narendra Singh and Kalyani Srinivasan (2016) Effect on Yield and Quality Attributes of Onion Grown Through Set and Seedling under Agro-Climatic Conditions of District Leh, Trans-Himalaya Ladakh, India. 7th Indian Horticulture Congress, November 15-18, 2016, New Delhi.

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