STUDIES ON FIELD APPLICATION OF SALICYLIC ACID, AZOXYSTROBIN AND CYCOCEL ON SHELF LIFE OF ONION CV. ARKA KALYAN

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CERTIFICATE

This is to certify that the thesis entitled "**STUDIES ON FIELD APPLICATION OF SALICYLIC ACID, AZOXYSTROBIN AND CYCOCEL ON SHELF LIFE OF ONION CV. ARKA KALYAN**" *submitted by* **MS. AYEESHYA H. KOLHAR (ID No. UHS15PGM620)** *for the degree of* **MASTER OF SCIENCE (HORTICULTURE)** *in* **POST HARVEST TECHNOLOGY** *to the University of Horticultural Sciences, Bagalkot is a record of research work carried out by her during the period of her study in this university, under my guidance and supervision, and the thesis has not previously formed the basis of the award of any degree, diploma, associateship, fellowship or other similar titles.*

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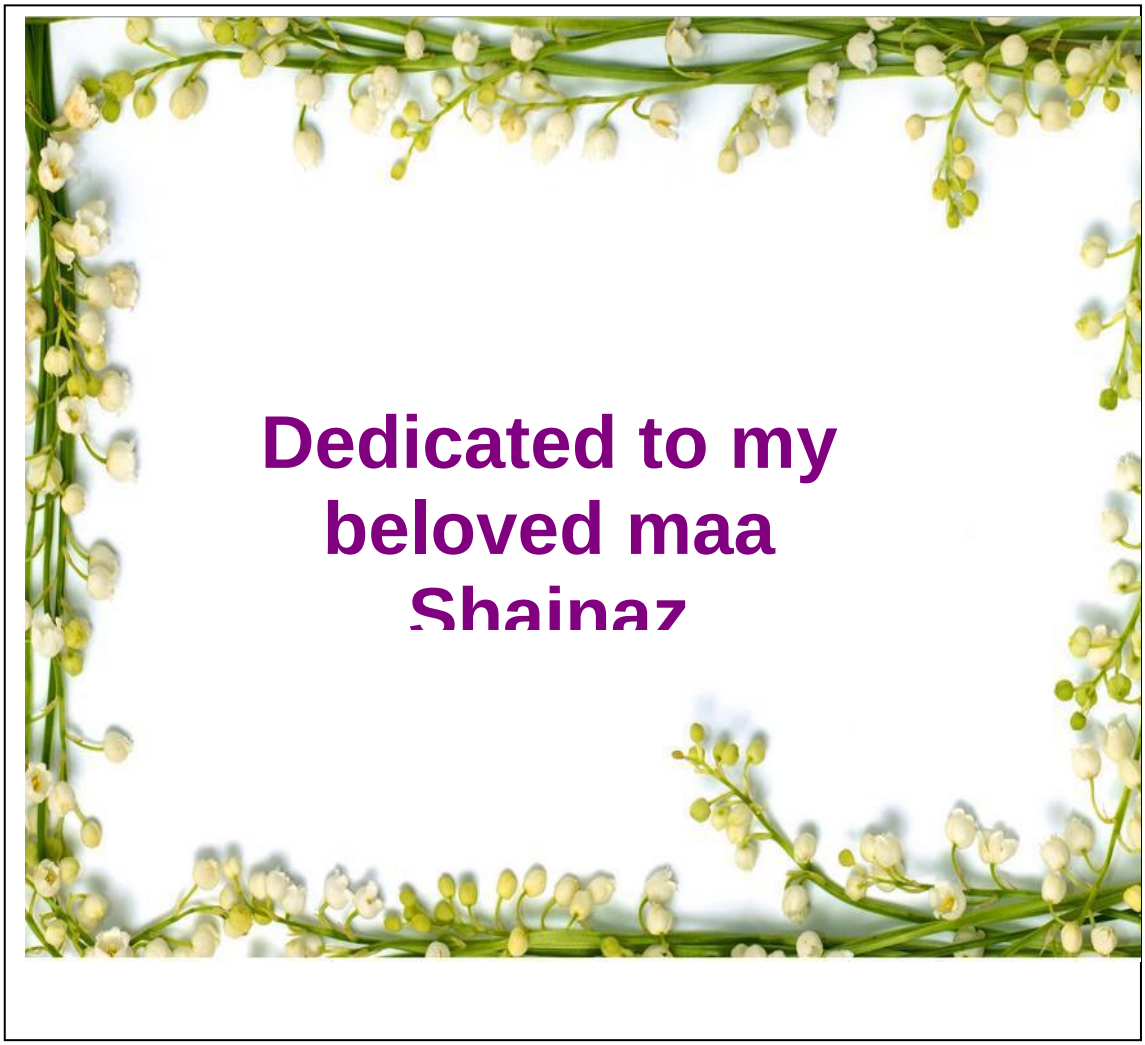
Dedicated to my
beloved maa
Shainaz

CONTENTS

LIST OF ABBREVIATIONS

Anon	: Anonymous
°B	: Degree brix
°C	: Degree Celsius
g	: Gram
h	: Hours
kg	: Kilo gram
DAS	: Days after storage
DAT	: Days after transplanting
RH	: Relative humidity
TSS	: Total soluble solids
Mg	: Milligram
SA	: Salicylic acid
MeSA	: Methyl Salicylate
mM	: milli molar
var.	: Variety
EC	: Electrical conductivity
PDI	: Plant Disease Index
PPO	: Poly phenol oxidase
PN	: Photosynthetic net
AOX	: Alternative oxidase
PG	: Poly galactouranase
PME	: Pectin methyal estarase

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1. INTRODUCTION

Onion (*Allium cepa* L.) belonging to family *Alliaceae*, is one of the oldest known vegetables to human beings. It is in continuous cultivation dating back to at least 4,000 BC with Central Asia being the probable centre of origin. It is an important commercial vegetable crop of India contributing great share to the national economy among the horticultural commodities both from internal consumption and export. India is the second largest producer of onion after china with area of 11.67 lakhs ha with production of 202.14 lakhs metric tones and productivity of 17.32 t/ha. Indian onion is exported to Sri Lanka, Malaysia, Maldives, Nepal, Dubai, Kuwait, Indonesia, UAE, Singapore, Seychelles, Pakistan, Saudi Arabia, Qatar and Bangladesh. There is growing demand for onion export from year to year. Recently about 9,80,566 tones of onion of worth ` 2,362 crores were exported in comparison to the previous financial year from ` 1,771 crores in the same period of the previous financial year by exporting 9,70,442 tones (Anon., 2016). Besides large quantity of onions are consumed within India.

In India, major onion producing states are Maharashtra, Karnataka, Madhya Pradesh, Gujarat, Bihar, Andhra Pradesh, Rajasthan, Haryana and Tamil Nadu. Karnataka is one of the leading States in the cultivation of onion. Dharwad, Chitradurga, Gadag, Haveri, Bagalkot, Davengere are the major districts in Karnataka occupying an area of 186.99 thousand ha with a production of 3227.04 thousand metric tons and productivity of 17.2 t/ha (Anon., 2015).

Due to widespread consumption, onion has acquired the status as queen of the kitchen. It has been used extensively to improve the taste of food and curry as it has special qualities, which add taste and flavour to food. Hence, it is used in all the traditional cooking and culinary preparations. In addition, it is also consumed as salad with meals. Onions are preferred for their green leaves, immature and mature bulbs are either eaten raw or cooked as a vegetable. Mild flavoured or colourful bulbs are often chosen for salads. The bulbs are used in soups, sauces, condiments, spice, medicine, seasoning of many foods and for the preparation of value added edible products like powder and flakes. A distinct characteristic of onion is its alliaceous odour, which accounts for their use as food. The pungency in onion is due to a volatile compound known as allyl-propyl disulphide. The onion bulb contains 88 per cent water. A 100 g

edible portion contains energy, 31 cal; protein, 1.5g; fat, 0.6g; total sugar, 7.2g; other carbohydrates, 0.3g; thiamin, 0.04 mg; riboflavin, 0.02 mg ; niacin, 0.1 mg; Vitamin C, 7 mg, 30 mg; Fe, 0.5 mg; Mg, 16.5 mg; K, 150 mg; and Na, 7 mg (Obeng-Ofori *et al*., 2007).

Onions possess many medicinal uses. Bulbs are commonly used as diuretic and applied on wounds and boils. A report suggested that it can prevent cardiovascular disease. It can also protect against stomach and other cancers, as well as certain infections. It can improve lung function, especially in asthmatics. The more pungent varieties of onion appear to possess the greatest concentration of health-promoting phytochemicals *i.e.* phenolics and flavonoids that have potential anti-inflammatory, anti-cholesterol, anti-cancer and antioxidant properties (Gopalakrishnan, 2010).

Onion is a seasonal crop of the total production in the country *rabi* (April-May), *kharif* (*October*-November), and late *kharif* (January-February) accounts about 60 per cent, 20 per cent, 20 per cent respectively. The *rabi* crop harvested in April-May is stored all over the country and slowly made available for domestic supply as well as for export up to October-November. There is a critical gap in supply in the country from October to December and as a result the prices shoot up. The good harvest in *kharif* season tries to bridge the gap. If there is failure of *kharif* crop due to vagaries of monsoon, the prices of onion further raise. The *kharif* crop therefore is more sensitive and vulnerable, yet essential. Hence, storage assumes a paramount importance for steady supply and nearly two million tonnes of onions need to be stored during this period (Tripathi and Lawande, 2003). Onion is a delicate commodity to store because of higher water content and serious losses occur due to rotting, sprouting, physiological loss in weight and moisture evaporation. Therefore, the crop requires special procedure and parameters for storage. But due to non-availability of appropriate post-harvest storage facilities, 25-30 per cent of the total onions produced are wasted and it amounts to crores of rupees (Chopra, 2010). In general, the losses due to reduction in weight, sprouting and rotting (decay) were found to be 30 to 40 per cent, 20 to 40 per cent and 20 to 30 per cent respectively (Shivakumar and Chandrashekar, 2014). Part of the blame lie in our ancient onion storage systems because traditional poor ventilated storage practices result in substantial losses in stored onions. Hence use of improved storage structures and good storer varieties, judicious use of fertilizers, timely irrigation,

scientific harvesting and post-harvest handling practices are essential to reduce the losses in stored onions**.** Onion storage structures made of bamboo (single tier or 2-tier) designed by NHRDF for on-farm-onion-storage can help in reduction of losses up to 8-15 per cent over conventional storage structures. These types of storage structures have better aeration from sides and bottom which help in taking out accumulated heat and humidity and minimize the decay and sprouting losses during storage of onion (Yadav *et al.*, 2011). Although improved storage structures for onion are developed, they are not popular among the farmers probably because of the higher cost of construction.

Some plant growth regulator and fungicides could be employed as pre-harvest foliar spray to extend the shelf life and reduce spoilage in onions as more scientific understanding of their action is known today. It is known that the use of synthetic growth regulators have their effects through changing the internal levels of the naturally occurring hormones, thereby causing the modification of growth and development in the desired direction and to the desired extent (Mathur,1971 and Singh *et al*.,1982). Plant growth regulators have contributed a great deal to the progress of horticultural science by modifying and controlling the growth behavior of many crop plants. They have, therefore, become one of the most important tools for horticulturists to increase crop production. Fungicides have been frequently used to prevent pre and post harvest fungal diseases there by preventing huge economic lossess caused by rotting.

Chloro choline chloride (CCC), also called as chlormequat, is chemically known as 2-chloro ethyl trimethyl ammonium chloride. Cycocel is one of the most extensively used plant growth retardants to control the vegetative growth of the plants and thereby enhances the production of a number of agricultural and horticultural crops. Cycocel is the most active member of the new group of quaternary ammonium compounds and is anti-gibberellin in its action (Anbukkarasi *et al*., 2013). Salicylic acid is being applied for enhancing photosynthesis, delaying the ripening and senescence process, alleviating chilling injury, enhancing antioxidant capacity, and controlling post-harvest decay (Mohammadreza and Morteza, 2010). Azoxystrobin brings about the cessation of normal energy production (ATP production) within the cell. Evidence of this effect on fungi can be observed in spore mortality, mycelial collapse and inhibition of sporulation or disruption of other vital stages of fungal development (Harrison and Tedford, 2002).

Despite the achievements in production technology, the post harvest losses during storage still pose a great problem. Due to non-availability of appropriate post-harvest storage facilities, nearly 1/3rd of the total onions produced are wasted causing economic loss to the farmer (Tripathi and Lawande, 2003). As most of the farmers in India are using traditional storage structures they end up in losing about 20 per cent of the crop due to rotting and sprouting (Anon., 2011). The losses that occur due to physiological loss in weight and moisture evaporation are not given much importance. The present experiment was carried out on popularly grown variety Arka Kalyan which has an average performance in storage. Therefore, pre-harvest foliar application of chemicals in the form of spray and seedling dip planned in this study are expected to improve yield in addition to reducing the losses due to rotting, sprouting, weight loss due to physiological process and moisture evaporation during storage.

The present investigation aims at reducing the losses that occur during traditional storage method, a similar condition as practiced by farmers were maintained during the investigation. This kind of chemicals are thought to be beneficial to maintain the quality of onion bulbs in storage with respect to inhibition of sprouting, rotting and reduction in the physiological loss in weight when applied as pre-harvest sprays and as a seedling dip. Keeping all these aspects in view, the present study was planned with the following objectives.

Objectives:

1. To determine the effect of seedling dip and pre-harvest foliar spray of salicylic acid, azoxystrobin and cycocel on storage behavior of onions

2. To study the shelf life of onions at regular intervals as influenced by different treatments

3. To study the biochemical quality of stored onions at regular intervals as influenced by different treatments

2. REVIEW OF LITERATURE

Onion (*Allium cepa* L.) is extremely important vegetable crop valued for internal consumption and is the highest foreign exchange earner among the fruits and vegetables. It is stored for long period for use in off season as well as for export but the present storage methods in India are quite inadequate and most of them are traditional and unscientific. Onion is reported to have good storage potential, but successful storage depends upon the variety, maturity, cultural practices and post harvest handling. Onions are stored either loose or in bags from May to November for a period of four to six months. However, 50-90 per cent storage losses in the form of rotting, sprouting, physiological loss in weight, moisture evaporation recorded are dependant upon genotype and storage conditions (Shivakumar and Chandrashekar, 2014). The curing techniques like neck cut in onion bulbs, exposure of onion bulbs in gamma radiation, packaging and storage techniques are proved to be useful methods in delaying sprouting and their subsequent deterioration resulting in improved shelf life of onion bulbs during storage (Anbukkarasi *et al.*, 2013).

There have been continuous efforts worldwide to prolong the storability of onions. The present investigation aims at prolonging the storage period of onion and maintaining the quality by employing seedling dip and different pre-harvest foliar sprays consisting of phenolic compound, fungicides and growth retardant. The research work carried out on various aspects revolving around post-harvest physiology of onion and the studies conducted in exploring the ways of extending the shelf life of onion and other horticultural crops have been reviewed here under.

2.1 Importance and production status of onion in India

The production of vegetables is becoming important with the expansion of irrigated area and with the growing awareness on the importance of the sector as source of income, improved food security, sources of raw materials for industries, employment opportunity because it demands large labour force. The expansion of water harvest schemes in small farmers sector and irrigated agricultural development projects have made significant contribution to the development of the sector. The success of production depends on the adoption of improved technologies such as

cultivars that have acceptable standard and high value in the local use and export markets (Lemma *et al*., 2006).

India is the 2nd largest producer of onion in the world next only to China occupying an area of around 1.67 lakh ha with production of 202.14 lakhs MT and productivity of 17.32 t/ha. Out of this, around 65 per cent produce which comes in *rabi* season is partly used for domestic consumption as well as storage for further consumption in different parts of the country from June to November along with the fresh produce of early *kharif* and *kharif* onion. The major onion storing states are Maharashtra, Gujarat, Madhya pradesh, Rajasthan and Bihar. As per the NHRDF's estimate, around 45-46 lakh MT onions have been stored in the year 2016-17 by farmers as well as traders which is around 15 per cent more compared to last year and quality is better. Around 12-15 lakh MT onions are required per month for consumption in the country (Anon., 2016).

Onion is a staple in Indian cuisine but often subjected to price fluctuation due to glut and shortage of onion, which is more common in India. Some times it has devastating consequences on ruling government because of price fluctuation as both consumer and grower are affected. In order to stabilize the price fluctuation, the government has banned exports of onions, slashed import duties and even imported onions from Pakistan during 2011. India's supply lines are clogged because of inefficient storage, poorly maintained roads and bureaucratised, centralised interstate commerce. In fact, it is outrageous; according to estimates, a staggering 30 to 40 per cent of Indian farm produce rots in poorly kept state-run warehouses.

2.2 Description of onion crop

Onion (*Allium cepa* L.) belongs to the family *Alliaceae* is one of the most important monocotyledonous crops. It belongs to the genus *Allium* and recent estimations accept about 750 species in the genus *Allium*, among them onion, garlic, leeks, and Japanese bunching onion are the most important edible *Allium* crops and about 60 taxonomic groups at sub-generic, sectional and sub-sectional rank (Baloch, 1994; *rabi*nowitch and Currah, 2002). Onion from Central Asia is probably migrated to the Near East. Then it was introduced to India and South-East Asia; and into the

Mediterranean area and from there to all the Roman Empire (Grubben and Denton, 2004).

Onion is a cross-pollinated cool season vegetable crop. It is the oldest known vegetable. Onion is an indispensable and important vegetable item which is used in every kitchen therefore its constant demand always remains throughout the year. Besides its high food value, it is also a good source of income for vegetable growers.

2.3 The onion lifecycle

Onion is a shallow rooted, biennial crop which is usually grown as annual. The leaves are long, hollow with widening, overlapping bases. The tubular leaf blades are flattened on the upper surface, and the stem of the plant is also flattened. Roots arise from the bottom of the growing bulb. Leaf initiation stops when the plant begins to bulb. The base of each leaf becomes one of the "scales" of the onion bulb, hence bulb size depends on the number of leaves present at the time of bulb initiation. The leaf base begins to function as a storage organ at bulb initiation, so the size of the leafy part of the plant also influences bulb size. Thus, the more leaves present and the larger the size of the plant at the onset of bulb initiation, the larger will be the bulbs and the higher will be the crop yield (Hamasaki *et al*., 1999).

An onion bulb is a storage organ, consisting of foliage leaf bases and swollen, bladeless inner sheaths that develop into distinct bulbs depending on the varieties. These bulbs are varying in size (small, medium and large), bulb weight, and the shape covers a wide range from globose to bottle like and to flattened disk-form. The colour of the membranous skins may be white, silvery, buff, yellowish, bronze, rose red, purple or violet. The colour of the fleshy scales can vary from white to bluish-red. There exist much variation among the bulbs for flavour and storability (Baloch, 1994; *rabi*nowitch and Currah, 2002).

2.4 Bulb initiation and formation

Bulb formation is the process whereby the leaves in the neck region of the sheath rapidly elongate (Brewster, 1977). The leaf sheath cells then expand resulting in lateral swelling of the leaf sheath. Scale leaves are formed instead of leaves, which

have a much reduced leaf blade in comparison to the sheath. The scale leaves then swell to form the storage tissue. As the bulb matures, two or three foliage leaf initials are laid down at the bulb base. These initials elongate to produce leaf blades in the following season when the bulb sprouts.

Bulb formation in onion plants occurs when both a threshold day length and accumulated thermal time have been reached (Lancaster *et al*., 1996). In the case of two closely related cultivars commonly grown in New Zealand (Pukekohe Longkeeper and Early Longkeeper), these thresholds are approximately13.5 hours and 590 degree days respectively. Threshold values will vary according to cultivar, however the thermal time threshold is thought to be linked with the requirement for a minimum number of leaves to be initiated prior to bulbing. If the threshold thermal time is reached before critical day length then bulbing is delayed and subsequent bulbs have larger diameters and more leaves. Conversely, the threshold day length can be reached before threshold thermal time has accumulated, and in this case bulbing is delayed until the thermal time requirements have been met. Light spectral quality interacts with day length (Brewster, 1990). Short-day onions form bulbs under short day lengths at low latitudes; however their behaviour is typical of other onions in that bulbing accelerates with increased day length (Wickramasinghe *et al*., 2000). Far-red light, and to a lesser extent blue light, promote bulbing, whereas red light inhibits it (Kahane *et al*., 1992). Once bulbing has been initiated, temperature (including night temperature) is positively correlated with the rate of bulb development in an inductive day length (Brewster, 1990; Wheeler *et al*., 1998).

2.5 Onion bulb dormancy

Mature onion bulbs enter a dormant period during which sprouting and rooting are not induced even under favourable conditions. For most cultivars, true dormancy is relatively short, and ends early in the storage period. Apparent dormancy is maintained for a short period, before sprouting certain internal changes occur leads breaking of dormancy. Sprouting occurs when the leaf primordia that are produced in stored onion bulbs develop green leaves rather than scale leaves (Abdalla and Mann, 1963). The blades of these leaves elongate, and eventually protrude from the neck of the bulb. Sprouting of bulbs varies with cultivar and pre and postharvest factors *i.e.*

maturity at harvest, curing, pre-storage treatment of chemicals (PGR, Pesticide) and storage environment. Sprout suppression is key point in determining the storage life of onions. Bulbs with roots sprout earlier in dry storage than those whose roots have been removed (Miedema, 1994). Therefore, the root system may provide substances that promote sprout growth or elongation. Cultivar differences in time to sprouting in store are more pronounced in de-rooted bulbs than in rooted bulbs (Miedema, 1994). Cytokinins produced in the roots stimulate cell division in the sprout meristem or increase the sink activity of the sprout. Wounding of the growth plate also promotes sprouting and may do so by facilitating gas exchange and promoting respiration.

2.6 Quality attributes of marketable onions

Onion bulbs are stored to meet consumer demands during offseason with good quality. The principal biological factors leading to onion bulb deterioration during storage are respiration, sprouting and rotting. Class I onions must not show any signs of external sprouting (Commission Regulation 1508/2001/EEC). Early signs of external shoot growth are permitted in Class II onions provided that the number or weight does not exceed 10 per cent per unit of presentation. Bulbs with watery scale and bacterial or fungal rots are deemed unfit for marketing.

2.7 Strategies to delay sprouting

Storage life of onions depends on the variety, pre and post-harvest treatment imposed and the storage environment *etc.* Varieties with long shelf life are having high dry matter content and varieties with less pungency and low dry matter are grown for the fresh market for raw consumption are getting popularised but are generally having poor keeping quality (Hurst *et al*., 1985). Research to develop strategies to delay sprouting has been focused on crop husbandry, pre and post harvest use of sprout suppressing chemicals, manipulating the storage environment and breeding programmes.

2.8 Pre-Harvest factors that affect storage life

Pre-harvest treatment and conditions in the field play an important role and affect the storage life. These include pre-harvest nutrition, temperature during the

growing season, application of plant growth retardants, chemical pesticides, maturity at harvest and the method of harvesting.

2.8.1 Crop maturity at harvest

Stage of harvesting plays a key role in determining the shelf-life of onions as it is linked with physiological maturity of bulbs. In general, one week after 50 per cent of neck fall is the stage recommended for harvesting. Sprouting and rotting are common problems in storage since bulbs contain high moisture. If bulbs are harvested too soon the water content in foliage leaves and the neck is too high, which results in increased susceptibility of bulbs to pathogen attack. Early harvested bulbs may not be dormant and would therefore be unfit for storage purposes. Maturity stage at harvest influences initial bulb weight, respiration and incidence of sprouting, decay and cumulative weight loss. Rutherford and Whittle (1982) found that bulbs harvested early, dried and stored in the same manner as bulbs harvested later, had lower carbohydrate levels, which were further reduced due to sprouting upon prolonged storage.

2.8.2 Harvesting method

Physical damage to onion bulbs during harvest should be minimised as much as possible especially for softer, less pungent onions, because wounding, particularly of the basal plate, causes accelerated sprout growth (Miedema, 1994a) and increases storage losses due to rotting (Herold *et al*., 1998). Undercutting is usually performed prior to mechanised lifting. The aerial parts and roots are removed before onions are stored in bulk, which aids airflow among the bulbs.

2.9 Post-harvest factors that affect storage life

Postharvest treatments and storage conditions play a kea role which affects shelf life of onion during storage. These include curing and drying, irradiation, post harvest treatment of chemicals (PGR, pesticide) and the storage environment.

2.9.1 Curing and storage

Onions before storage are generally cured and dried after harvest (Gubb and MacTavish, 2002) to prolong shelf life during storage. It is the removal of excess moisture from the outer skin and neck portion of onion which helps in reducing the infection of diseases. It is done till the neck is tight and outer scales are dried. The bulbs should be adequately cured for proper development of skin colour and to remove field heat before storage of bulbs. Curing of onion bulbs can serve several functions. It dries the outer most two to four scale leaves, it can provide mechanical protection to the bulb. It dries the remaining roots attached to the bulb and the neck left attached to the crown, which protect against disease infection. It also discourages loss of moisture and the sealing of wounds on the bulbs. During curing moisture is removed from the skin, roots, and stem of onion bulbs. The skin dries and becomes uniform in colour, show a brittle texture. The roots shatter or break off easily when touched. The stem area shrinks in size and dries to the surface of the bulb. It may not slide back and forth when squeezed between the thumb and forefinger (Paul and William, 2008). Bernard (2004) suggested that onions have to be cured before storage because during curing, the outer scale leaves and neck dry out and shrink. This will prevent infection of disease and minimize shrinkage loss. Curing heals wounds and strengthens general skin condition of the bulbs as reported by Moude *et al*. (1984). The purpose of curing is to dry the thin outer layers of the bulb to form one or more complete outer skins. These outer skins act as a barrier against water loss and infection from fungal pathogens such as *Botrytis allii* (neck rot) (Maude *et al.*, 1984), *Aspergillus niger* (black mould) and *Fusarium oxysporum* (basal rot), and bacterial pathogens such as *Erwinia carotovora* (soft rot) (Fenwick and Hanley, 1985). Curing is complete when the necks have dried out and are tightly closed, and the skins have an attractive colour (O'Connor, 1979). Bulbs are cured either in field or in open shade or by artificial means before storage. During *kharif* season, bulbs are cured for 2-3 weeks along with top. In *rabi*, bulbs are cured in field for 3-5 days, tops are cut leaving 2-2.5 cm above bulb and again cured for 7-10 days in shade to remove field heat (Gopalakrishnan, 2010).

Curing can be accomplished by placing onions in crates exposed to ambient air of 75 to 80^{o}F for 2 to 3 weeks. Onions can be cured in storage by forcing warm air (90^{o}F) through the pile for 4 to 5 days. The air requires an initial relative humidity of

60 to 70 per cent. Exit the hot and saturated air from the storage and not be recycled. Air volume is required at least 1.5 cubic feet per minute for each cubic foot of onions. Pandey *et al.* (1992) reported that curing in the sun or a solar drier with or without foliage reduced per cent weight loss significantly compared with non-cured bulbs. The lowest per cent total loss obtained with curing in the sun with foliage and storage of bulbs with dried foliage. Pandey *et al.* (1993) found that the lowest loss (1.8%) due to decay (mainly *Fusarium oxysporum*) occurred in bulbs stored with foliage removed at harvest and no curing. Per cent total loss was highest in bulbs with foliage removed at harvest and cured in sun before storage and lowest in bulbs cured in sun with foliage attached and stored with dry foliage followed by bulbs cured in sun with foliage attached but with dry foliage removed prior to storage. Bhonde and Bhadauria (1995) reported about small onions grown in Karnataka for export to Malaysia and Singapore. To meet the continued demand for export during the off season onion has to be stored for 2-2.5 months. Therefore, in a trial bulbs were subjected to various field curing treatments (or not cured) before being stored under ambient conditions in nylon net bags. Losses due to sprouting and physiological loss in weigh were greater after 4 than 2 months storage in all treatments. Bulbs stored for 2 months showed the lowest losses (<13 %) when bulbs cured in the shade (with foliage) then cooled before storage. Curing in the sun with foliage then removing the foliage before storage also resulted in low losses after 2 months storage. Losses of non-cured bulbs after 2 months storage were 16.1% with neck cutting and 26.8% without neck cutting. Chauhan *et al.* (1995) found that lowest total storage losses occurred with the windrow method with 10 days in the shade with tops and cutting the neck to 2.5 cm. They concluded that physiological weight loss was the main cause of storage losses, followed by decay and sprouting. Bhonde *et al.* (1996) recorded lowest sprouting, decay and total losses in storage when harvesting was done 12 days after the last irrigation and bulbs were cured for 3 days. Wright and Grant (1997) found that application of additional water during field curing increased the proportion of bulbs with stained skins and rots. Heated air curing of bulbs reduced the incidence of rots regardless of harvest method. Forced air drying also reduced skin staining in most harvesting methods.

Field curing by windrow method for three to five days and shade curing with tops for 10 to 12 days by retaining 2.5 cm neck length is effective in reducing storage losses in onion along with color retention and development of more number of scales

upon storage for longer period (Singhal, 2000). As scale leaves play an important role in bulb firmness. The absence of dry scales induced a more rapid breaking of dormancy both in terms of rooting and sprouting. The defective scales and damaged stem base were prime factors in breaking dormancy. Late harvest resulted decrease in the number and quality of the dry scales Fustos *et al.* (1997).

According to Satish and Ranganna (2002a), onion bulbs were best cured in the artificial curing for 10 to 14 hours at 45°C with air flow rate of 222 m^3 per minute compared to 8 to 10 days of sun curing. The artificially cured bulbs showed significant increase in firmness (9.75 to 10.5 kg/cm^2) along with development of an attractive colour in comparison with the sun curing. Curing of onion bulbs for 7 days before storage results in lowering the PLW of 31.9 per cent in comparison to control (without curing) which is about 43.90 per cent during storage of 120 days (Bhattarai and Subedi, 1998).

Bottner (1970) studied the effect of different temperature during curing and observed that bulbs cured in cool air ventilation resulting in reduced the rotting of onion during storage. Thampson *et al*. (1972) studied the effect of curing methods on storage behaviour of onions and found that both field and artificial curing methods were superior in reducing physiological loss in weight and rotting percentage in comparison to non-cured bulbs stored for 87 days. Goburdhan (1980) reported that field curing of onion bulbs for 21 days extends the storage life upto five months in comparison to control which is stored for three months.

Field curing by way of pre-drying bulbs in shade for about three to fifteen days was found to improve the storability of onion (Sidhu and Chadha, 1986) and further observed that the tops where removed after 15 days of storage gave reduced sprouting (the neck of the bulb was completely dried and turned deep red in colour) in comparison to the bulbs in which tops are removed immediately. Field curing of onion by retaining 4 cm neck length for four days results in reduced losses due to sprouting, rotting and shrinkage (Anon., 1986).

Curing of onion bulbs for four days in the field by Windrow method followed by curing in shed for 21 days before storage decreased the reducing sugar content which improved the storage life of bulbs. Bulbs stored after full curing treatment

recorded lower storage losses (38.70%) compared to non-cured bulbs (47.80%) (Kale *et al*., 1992). Sanguansri and Gould (1990) observed that artificial cured onions had lower weight loss and enhanced colour and firmness than to field cured onion bulbs.

Warade *et al.* (1997) found that curing of onion in the field for 4 days by Windrow method followed by shade curing for 21 days resulted in decreased levels of reducing sugars and improved storage life of bulbs. Pandey *et al*. (1992) found that lowest per cent loss due to sprouting and physiological loss in weight was noticed in sun cured onion bulbs with foliage.

Schroeder *et al*. (2012) reported that among two cultivars of onion (Redwing, Vaquero) Redwing bulbs exhibited significantly less severe rot (23.1 ± 1.1%) than Vaquero bulbs (46.0 ±1.3%) inoculated with *B. cepacia* (1 × 105 CFU/ml), and the severity of sour skin increased significantly with increasing postharvest curing temperature (14.2 ± 0.9, 24.3 ± 1.3, 42.2 ± 1.7 and 57.6 ± 1.8% at 25, 30, 35, and 40°C, respectively). The mean severity of sour skin was significantly less for bulbs cured for 2 days (24.5 ± 0.9%) versus 14 days (44.8 ± 1.4%), and increased significantly with increasing duration of storage (27.8 ± 1.3, 35.5 ± 1.6, and 40.6 ± 1.7% for 1,2, and 3 months of storage, respectively). The results indicated that the severity of sour skin and slippery skin in onion storage facilities can potentially be minimized by using relatively low post-harvest curing temperatures (<35°C) and short curing durations (approximately 2 days).

In yet another study, onion bulbs were cured (14 days under partial shade) with and without foliage, and stored under different conditions *e.g.,* cold store, cemented room and mud room for four months. Results indicated that the quality of onion bulbs was significantly affected by curing methods, storage conditions and duration. The maximum dry matter (DM) (17.5%) and TSS (11.5%) was recorded in bulbs cured with foliage as compared to curing without foliage (15.7% DM and 9.36% TSS). The DM (21.2%) and TSS (14.9%) recorded in cold stored bulbs was followed by those in mud and cemented room storage (15.65 and 13% DM with 9.44 and 6.65% TSS). Curing with foliage resulted in significantly lower weight loss, sprouting and rotting. After four months storage, the minimum percentage of weight loss (6%), sprouting (9.6%) and rotting (1.7%) was recorded in cold stored bulbs while the maximum

weight loss (98%), sprouting (100%) and rotting (70%) was observed in bulbs stored in cemented room (Nabi *et al.,* 2013).

2.9.2 Storage temperature

Temperature has a profound effect on the dormancy period and storage life of onion bulbs. In general, sprouting was inhibited both by low and by high temperatures, and encouraged at intermediate temperatures (Abdalla and Mann, 1963; Brewster, 1977a; Miedema, 1994a; Ernst *et al*., 1999). Different cultivars respond differentially to temperature (Gubb and MacTavish, 2002). The optimum temperature range for sprouting in dry storage is 10-20ºC for most cultivars, with some cultivars displaying a sharp optimum while others have a broader range. Moisture loss is greater at temperature ranges <10 ºC and >27 ºC.

In developed temperate countries, such as the UK, onions are kept in large, specialized stores. Ventilation is forced and temperature is usually maintained around 5ºC, but can be as low as -1ºC. In warm climates, such as the tropics, high temperature storage is a practical option, but involves a compromise between sprouting losses and rotting losses (Ko *et al*., 2002). High temperature storage conditions are generally 25-30ºC and 60–75 per cent RH. Ventilation of storage bins to reduce fluctuations in temperature and humidity reduced the rate of external sprouting, bacterial infection and dehydration over 31 weeks of high temperature storage in red onion cv. Baftain bulbs (Brice *et al*., 1995). The high temperature inhibition of sprouting may be related to the dormancy observed in hot seasons in some wild *Alliums* (Gubb and MacTavish, 2002). Short-term (three weeks) high temperature post-harvest treatments of 30 and 35ºC significantly reduced the number of days to sprouting in dry storage at 15ºC, when compared to those exposed to post-harvest temperature treatments of 15 and 25ºC, which in turn were not significantly different from one another (Miedema, 1994a). This indicates that exposure of onion bulbs to high temperatures during curing and drying may reduce the level of dormancy and therefore reduce storage time.

2.9.3 Humidity

The relative humidity of the storage environment is a compromise between maintaining a level below that at which pathogens are encouraged and above that at which water is rapidly lost from the bulbs (Hole *et al*., 2000). The outer skins that protect against water loss tend to crack and fall off at <55 per cent RH, and pathogen attack is encouraged at >80 per cent RH, therefore 55-80 per cent RH is desirable in the storage environment.

When the water content of the skin is in equilibrium with the water vapour pressure of the surrounding atmosphere, water will be adsorbed or desorbed depending on the relative pressure. Changes in humidity, therefore, have an impact on the properties of onion skins. This is significant as the ability of onion bulbs to withstand physical abuse during post-harvest and post storage handling depends on the mechanical properties of the skins.

2.9.4 Effect of Storage on bulb quality

Physical injury, rotting and re-growth (sprouting and rooting) are the main contributory factors of deterioration in onion bulbs during storage. These factors increase respiration rate, which consequently increase moisture loss and reduce the shelf life of the produce (Nandasana, *et al.,* 1998). Moisture loss itself is a major concern in post harvest life because loss in weight during storage is loss in economic value to farmers and the traders as well (Trevisan, *et al.,* 1999). Onions required to be stored at 0°C (32°F) and at 65 to 70 per cent relative humidity. Temperatures above 0°C (32 °F) may cause the onion to sprout. Sprouting leads the bulb to rot and increase moisture loss. Relative humidity exceeding 70 per cent may cause the onion's roots to sprout. Air movement through the pile is beneficial to reduce disease spread that could occur from a wet pile (Doug, 2004).

The length of time an onion may be safely stored will depend on the degree of maturity and the variety, which will determine its dry matter content. Yellows are the best storage onions, followed by reds, whites and then Spanish onions. The more pungent the onion (*i.e*. yellows and reds), the longer it usually can be stored. The sweeter it is, (*i.e*., Spanish), the poorer storage onion it will be (Doug, 2004). Santiago

et al. (2003) cured medium-size Red Creole onion through sun drying and site drying, placed in net bags and wooden crates with net capacity of 20 kg and stored at 27^{o}C and in cold room at 0^{o}C. They found that bulbs stored at 27^{o}C lasted for 13 weeks with 100 per cent rotting while bulbs stored at 0^{o}C were prematurely terminated on the 17 week of storage with high percentage of sound bulbs. Bulbs in 27^{o}C incurred a 10 per cent weekly rate of rotting compared to 1 per cent rotting at 0^{o}C. Bulbs in net bags incurred 8 per cent weekly rate of rotting while 4 per cent of bulbs in wooden crates rotted. Sun dried bulbs had relatively lower bulb rot incidence regardless of storage temperature and packaging material. Bernard (2004) suggested that after curing, gradually decrease the storage temperature. A few warm days may cause moisture to accumulate on the bulbs and result in discoloration and potential decay of bulbs.

2.9.5 Effect of diseases on the shelf life and quality of the bulb

Beside improper cultural practices, a number of bacterial and fungal infections are responsible for various diseases that lead to decay of the bulbs during storage. A fungal infection neck rot is caused by Botrytis during pre-harvest time. Neck rot is often the most serious cause of post harvest losses in Onion. The fungus may spot leaves and causes die back of leaves and spread from cut leaves to the bulb scales (Snowdon, 1990). The scales become water soaked and light to dark brown in color. The fungus persists from one season to the next on onion waste and by *sclerotia* on soil. Its conidia are dispersed by wind or splashing rains (Eckert, 1988). The symptoms usually appear during the storage. The disease causes the scales to become water soaked and brown in colour with odd smell when the scales are exposed. High humidity is highly conducive for the spread of fungus (Eckert, 1979). In addition to neck rot, several other fungal rots such as basal rot, bacterial rot, black mold rot and blue mold are commonly problems in stored onion. The incidence of several fungal and bacterial rots can be minimized by effective pre or post harvest diseases control measures (Srivastava and Tiwari, 1997). Wright (1993) reported that levels of bacterial soft rot (caused by *Erwinia carotovora subsp. carotovora, Pseudomonas marginalis, P. viridiflava and P. gladioli pv. alliicola*) in stored onion bulbs were affected by rates (double the local recommended rate) and application times of nitrogen (N) fertilizer (late in the growing season), at the time of harvesting and water (supplementary irrigation) during the field-curing period. Hassan (1996) reported that

higher irrigation led to higher susceptibility of onion bulb to storage diseases (*Botrytis allii, Pseudomonas marginalis* and *Erwinia carotovora*). Early harvesting of onion resulted in decreased susceptibility of bulbs to infection with storage pathogens. Maturity stage had a slight effect on predisposition of bulbs to the tested pathogens during storage.

It is evident from the previous work that various aspects of pre and post harvest handling need to be optimized under local conditions to decrease post harvest losses in onion and develop a package of post harvest technology for the onion bulbs. With proper technology, the growers will be able to produce good yield and quality onion and India will in a better position to explore international markets for its onion export.

2.9.6 Alternative strategies to delay sprouting

Increasing awareness among the consumers towards food safety pressurized the retailers to provide food with little or no chemical residues *i.e.* continuing use of MH to extend onion storage life is far from certain, and alternative strategies must be explored. In order to identify potential targets for manipulation to suppress sprouting in storage, it is useful to examine what changes occur in stored onion bulbs.

2.9.7 Physiology of onion with respect to sprouting

Sprouting is the physiological phenomenon that comes after dormancy breakage, and it is a major problem during the storage of onion. Sprouting is defined as the condition when the stem apex of an onion shows signs of bursting through the neck. Sprouting in an onion requires nutrients, and these nutrients must come from the onion. Therefore, changes in the characteristics of biochemical compounds and plant hormones could be used to predict the onset of sprouting. Miedema and Kamminga (1994) investigated the timing of rooting and subsequent sprouting and concluded that roots appear first, followed by sprouts. The reason for sprouting has been investigated by a number of scientists with respect to the growth inhibitors (Miedema and Kamminga, 1994) and temperature (Benkeblia and Selselet 1999, Miedema, 1994). Pak *et al.* (1995) stated that the major factors responsible for sprouting are the length of dormancy period (if it is present; in some cultivars such as Hysam, Hystat, and

Centurion, there is no dormancy period) and the sprout growth rate. Sprouting is accompanied by many physiological changes, including increases in reducing sugar content, respiration, water loss, and change in plant growth regulators (Tucker, 1989)

Sprouting begins with the reallocation of water and metabolites from scales to a base plate. The sprouts originate from this base plate (Chope, 2012) and this reallocation of phytonutrients is responsible for the formation of new cells and cell elongation. Before harvest and during sprout growth, there is an increase in mitotic activity in onion meristem, and significantly less activity is found during dormancy (Matejko and Dablbelm, 1991). Pak *et al.* (1995) reported that the sink strength (carbohydrate usage in the bulb base) increases gradually with the increase in mitotic and sucrose synthase activities during sprouting and the initiation of leaves. It is very difficult to record internal sprouting because dormancy terminates as soon as internal sprouting starts. Therefore, it is only possible to determine internal sprouting if onion is cut longitudinally in two halves. This contrasts with rooting, which is superficially located on a ring around the base plate and can be recorded easily. Miedema (1994) reported that, at the same temperature, rooted bulbs sprout earlier than nonrooted ones. It has been postulated that the root supplies specific organic substances, called cytokinins, which have been utilized for onion sprout growth. The supply of cytokinin from roots to sprouts was proven by the application of benzyladenine in derooted bulbs in a few cultivars, resulting in sprouting in the derooted bulbs. cytokinins play a role in sprouting by stimulating cell division. Removal of the primordial roots gives less chance for the accumulation of cytokinins, and ultimately inhibits sprouting.

2.9.8 Physiology of onion with respect to dormancy

Onion bulbs have high water content and display an active life after harvesting. Onions are characterized by three major periods: rest, dormancy, and regrowth (sprouting). After harvest, onions go through a rest period for 4–6 weeks, and during this rest period, they do not respond to rapid environmental change and there is no visible cellular activity (Jones, 1920). The activity of endogenous hormones (cytokinins, gibberellins, and auxin) is very low, and inhibitor activity is high. After completion of the rest period, the onion enters its period of dormancy. It has been postulated that after removal from the ground or immediately after harvest, onions are

in a state of natural dormancy, controlled by the various endogenous hormones, and also varying with the genetic makeup of the particular cultivar (Benkeblia *et al*., 2005). During dormancy, onion bulbs respond to environmental changes. The effect of this environmental change is slower in the early stage of dormancy and more rapid in the later stage until dormancy is finally lost. The duration of dormancy varies from several weeks to months depending on the cultivar, and the methods used in the determination of dormancy and sprouting (Carter *et al*., 1999). According to Espen *et al.* (1999), dormancy in onion bulbs is a physiological state that could be linked to the metabolic changes following the source-to-sink transition, when the bulbs are prepared to sprout. The metabolic activity in onion depends on the source-to-sink transition; the source (scales) is where the carbohydrates are produced and the sink (base plate) is where they are consumed during the sprouting in onion. Even though the onion bulb is in its dormant stage, the source-to-sink transition takes place at a greatly reduced level that keeps the bulb metabolically active, but the change is unnoticeable (Lang *et al*., 1987). During dormancy, the enzymatic activity is very low, especially the activity of invertase, which results in reduced levels of metabolic activity in onion, but it is relatively rapid during other stages, such as sprouting. Dormancy period is followed by a period of internal change that prepares bulb for dormancy breakage and subsequent growth, which finally results in visible changes in onions. Storage regime also affects the onion dormancy and biochemical changes in onion. These biochemical changes include the change in water content, the concentrations of flavour-related compounds, (Uddin and MacTavish, 2003) organic acids, (Salama, 1990) carbohydrate content, (Benkeblia *et al.*, 2005; Rutherford and Whittle 1982) phenolics, (Benkeblia 2000) and endogenous growth-related compounds (Thomas 1969; Thomas and Isenberg, 1972). Understanding dormancy of onion will help in maintaining quality for marketing and ensuring its continuous supply even when the environmental conditions are not suitable for the production of onion. In order to maintain quality, onions are placed into medium- to long-term storage with the treatment of synthetic sprout inhibitors (maleic hydrazide, exogenous ethylene). Regardless of the efforts taken by breeders and growers, there may be losses that occur from lack of detailed understanding of the physiological bases of onion dormancy and sprouting.

2.9.9 Changes occurring in onion bulbs during storage and sprouting

Many characteristic changes which occur during storage are change in water content, concentration of flavour compounds, carbohydrates, minerals and plant growth regulators. Changes in these characteristics are likely to be linked with respiration and remobilisation of carbohydrates to provide energy for the growing sprout. All nutrients required for growth of the sprout are usually supplied from bulb itself; therefore changes in certain key characteristics can be used to predict the onset of sprouting. Peaks and troughs in certain substances are known to coincide with sprouting but there is currently no biochemical assay that anticipates sprouting (Chope, 2006).

2.9.10 Flavour precursors and pungency

Onions, and other *Alliums*, are eaten for their unique taste and the medicinal properties of their flavour compounds (Randle, 1997; Griffiths *et al*., 2002). The flavour compounds are secondary metabolites whose biosynthesis involves the metabolism of cysteine and glutathione, which are essential pathways for uptake of sulphur and detoxification (Jones *et al*., 2004). Sulphate is taken up by the roots, reduced to sulphite and assimilated into cysteine. The tripeptide glutathione is formed and converted into *S*-2-carboxypropyl glutathione which is metabolised through many glutamyl peptides, terminating in *S*-alk(en)yl-L-cysteine sulphoxide (ACSO) synthesis (Block, 1992; Kopsell and Randle, 1997). The ACSOs make up 1-5 per cent of the dry mass of an onion bulb and is responsible for the characteristic flavour and odour of onions. Intact onion cells have no flavour, but when cells are disrupted the vacuolar enzyme alliinase (*S*-alk(en)yl-L-cysteine sulphoxide lyase) hydrolyses the flavour precursors (ACSOs) present in the cytoplasm. The products of this reaction are pyruvate, ammonia and unstable alk(en)yl sulphenic acids (Uddin and MacTavish, 2003), which spontaneously condense in pairs to form thiosulphinates that contribute to perceived flavour (Briggs and Goldman, 2002). The three major ACSOs present in onion are methyl (MCSO), propyl (PCSO) and 1-propenyl (PRENCSO) cysteine sulphoxide. PRENCSO gives rise to the lachrymatory factor, thiopropanal *S*-oxide (Lancaster *et al*., 1998; Kopsell *et al*., 1999). The production of the lachrymatory

factor was thought to be spontaneous, but further investigation has revealed that it is specifically synthesised by an enzyme known as lachrymatory factor synthase (Imai *et al*., 2002). The composition and concentration of ACSOs determines the nature and intensity of flavour and odour. Total ACSO content is also positively correlated with enzymatically produced pyruvate (Kopsell *et al*., 1999). Variations in flavour between cultivars, and changes that may occur in flavour during storage are due to the differences and differential changes in the ACSOs present in bulbs and their alliinase activity. A highly significant correlation exists between threshold olfactory perception (the minimum concentration of onion juice in water that could be detected by 70% of the judges) and enzymatically produced pyruvic acid (Schwimmer and Weston, 1961; Schwimmer and Guadagni, 1962). This suggested that the same enzyme system that produces volatile odour compounds when the cells of onion are disrupted, also gives rise to pyruvic acid, and that pyruvic acid concentration was a good indicator of pungency. Selection for less enzymatically produced pyruvate resulted in a milder onion (Havey and Randle, 1996; Havey, 1999). Relative pungency is dependent on both genetic and environmental factors (Havey and Randle, 1996; Havey, 1999). It is possible for pungency to increase, decrease or stay the same during storage (Uddin and MacTavish, 2003).

Pyruvate analysis measures total pungency but does not estimate the relative amounts of individual flavour precursors or final flavour volatiles. The pyruvate concentration in onion bulbs ranges from 1.6 μmole/g fresh weight in mild to 13 μmole/g fresh weight in pungent cultivars as found by Randle (1992). The high correlations between flavor perception and enzymatically produced pyruvate demonstrate that pyruvate analysis is a useful method for measuring onion pungency. Pyruvate analysis would be less expensive and more objective than tests for evaluations of several hundred bulbs (Abrameto *et al*., 2010). There are different methods to assess the pungency like HPLC method and spectrophotometric method as reported by Gallina *et al*. (2012). The concentration of pyruvate in onion sample expressed as mol g^{-1} fresh weight can be calculated using a calibration curve constructed using the due to differences in availability of alk(en)yl cysteine sulfoxides. Pyruvate produced by hydrolysis of the ACSOs can be estimated using dinitro phenyl

hydrazine (DNPH) (Schwinner and Weston, 1961). Absorbance of pyruvate phenylhydrazone is measured spectrophotometrically at 420 nm after mixing onions with water (1:1), filtering, centrifugation and dilution before analysis. Randle and Bussard (1993) developed a fast juice extraction method using a pneumatic press, eliminating blending bulb tissues with water.

2.9.11 Carbohydrates

Series of oligosaccharides and water-soluble carbohydrates *viz.* Glucose, fructose and sucrose referred as fructans constitute around 60-80 per cent of the dry weight of onion (Rutherford and Whittle, 1982). With prolonged storage, fructose and sucrose levels increased with time due to enzymatic hydrolysis of oligofructans (Salama *et al*., 1990) and fructan levels decreased as are used in respiration (Suzuki and Cutliffe, 1989; Ernst *et al*., 1998). It has been postulated that carbohydrate content is directly correlated with storage life. Higher fructose content at harvest was correlated with extended storage life in onion cv. Robusta bulbs stored at 4°C for three months (Rutherford and Whittle, 1982). The maximum soluble sugar concentration was less in the bulbs stored at 4°C, as were the concentrations of tetra, penta and hepta saccharides, probably due to decreased enzymatic hydrolysis of fructan polymers by depolymerases. The similarity in the pattern of change in total soluble sugars at different temperatures suggests that the catabolism of carbohydrates is more dependent on physiological stage than temperature. In contrast, fructose concentration was higher in onion cv. Sentinel bulbs stored at 0 and 15ºC than in those stored at 30ºC, suggesting that hydrolysis of fructans increased at low temperatures (Salama *et al.*, 1990). A net increase in total sugars was observed at 0ºC, and a net decrease observed at 15 and 30ºC (Benkeblia *et al*., 2002). The pattern of changes in total soluble sugar content of onion cv. Rouge Amposta bulbs is similar at 4, 10 and 20°C, with a maximum concentration occurring at approximately seven weeks of storage.

Storage life of onion cultivar c**a**n be easily predictable by determining dry matter and fructans content at harvest. Therefore, the proposal of Rutherford and Whittle (1982) to use estimations of fructose and dry weight at harvest as indicators of storage, medium and long storage life. Fructans concentration in ground lyophilized bulb can be measured using a fructans assay kit (O' Donoghue *et al*., 2004).

2.9.12 Physiological loss in weight and water loss

Water accounts for 80-93 per cent of the fresh weight of freshly harvested onions. The actual amount depends on cultivar and growing conditions. Water loss during curing and drying is rapid and is around 5 per cent of fresh weight (Gubb and MacTavish, 2002). Water loss continues throughout storage because of evaporation and low-level of respiration. Onion sown in *rabi* season are harvested in May month, kept in ventilated room under ambient storage condition at temperature range 26 to 36°C, showed total storage losses which ranged from 13 to 43 per cent. Physiological loss in weight was found to be the major factor responsible for the highest loss during storage and it ranged from 20 to 87 per cent (Sidhu, 2008). Since the water loss is a function of storage temperature and relative humidity, high rate of water loss in the cultivar could be partly due to the high temperature and low relative humidity during storage.

2.9.13 Respiration

Respiration is oxidative breakdown of complex substances into simple molecules such as water and CO_2. It is necessary evil and has negative correlation with shelf life of produce during storage. It can be measured in mmol CO_2 kg^{-1} h^{-1}. The high rate of respiration indicates a higher oxygen consumption and an intense metabolic activity mainly carbohydrate catabolism (Benkeblia and Shiomi 2004). Chope *et al*., (2007) reported that respiration of onions after two months at 20°C increases nearly 50 per cent of the freshly harvested bulbs. The increase in the respiration rate of onion is the consequence of physiological changes where this period corresponds to the break of dormancy and the onset of sprouting even if sprouts are not emergent from the necks. In India, long-term storage of onion bulbs is important for maintaining a continuous supply to the industry and domestic use. Brewster (1977) assessed that bulbs harvested at the beginning of September by hand, when 80 per cent of the plants had fallen tops, field cured for 21 days dried at 24°C for 35 days and then stored untopped at 1°C and relative humidity (RH) 75 to 80 per cent for an additional 7 months. In general sprouting is inhibited both by high as well as low temperatures and encouraged at intermediate temperatures as observed by (Brewster, 1977). The Q_{10} of a respiration rate represents the increase in the respiration rate produced by raising the

temperature by 10°C. Benkeblia *et al*. (2000) observed that the Q_{10} of onion *cv.* Rouge Amposta bulbs O_2 and CO_2 respiration rates were 1.67 and 1.84 respectively. The respiration rate of oxygen increased throughout storage, doubling within 15 weeks at 20°C and 20 weeks at 10°C. At 4°C the increase was only slight.

Respiration rate is dependent on the physiological state of the bulb (Ogata, 1961; Benkeblia *et al*., 2000). The respiration rate of a sprouted bulb is greater than that of a non-sprouted bulb sampled simultaneously. The high rate of respiration indicates a higher oxygen consumption and an intense metabolic activity mainly carbohydrate catabolism (Benkeblia *et al*., 2004). Chope *et al*., (2007) reported that respiration of onions after two months at 20°C increases nearly 50 per cent of the freshly harvested bulbs. Brewster (1977) assessed onion bulbs harvested at the beginning of September when 80 per cent of the plants had fallen tops, field cured for 3 weeks, dried at 24°C for 5 weeks and then stored untopped at 1°C and relative humidity 75 to 80 per cent for additional 7 months. Sprouting was inhibited both by low and high temperatures and encouraged at intermediate temperatures. The use of controlled atmosphere storage extends storage life of onion bulbs; however, as relative humidity was high within the storage chambers, disease often ended storage life before external sprouting occurred. Respiration of harvested crops is highly dependent to ethylene production and activity and any factor increasing the production and activity of ethylene leads to increases in respiration and consequently increases the senescence rate.

2.9.14 Dry matter content:

Dry matter content is the primary characteristic of onion bulb quality, determining, in part, the end use (e.g. as salad, cooking or dehydrated onions), storage life, pungency and firmness (Sinclair *et al*., 1995a). Onions with high dry matter content tend to be much firmer and store for longer periods before shoot growth and disease incidence deplete the number of marketable bulbs (Darbyshire and Henry, 1979; Rutherford and Whittle, 1982; Suzuki and Cutliffe, 1989).

During the drying and storage period the dry matter content was significantly higher in the newer, inner leaf bases than in the older, outer leaf bases of onion (Darbyshire, 1978; Rutherford and Whittle, 1982). Onion outer leaf bases containing

larger cells that have a lower percentage of dry matter content than the inner leaf bases as reported by (Darbyshire and Henry, 1979). Onion cultivars characterized by low dry matter content tend to accumulate simple sugars such as glucose and fructose during bulb formation, whereas those characterized by high dry matter tend to accumulate more fructans. A positive relationship between fructans content at harvest and storage life has been reported (Suzuki and Cutliffe, 1989). Supporting this relationship, bulb fructans concentration before storage was greatest in the cultivars with the longest storage potential. Fructans concentration would be expected to decrease over time as they are enzymatically hydrolysed to fructose found by Hurst *et al*. (1985). High fructans concentration may protect against tissue damage caused by anaerobic respiration under low oxygen conditions Ernst *et al*., (2003).

The higher dry matter content recorded in bulbs cured and stored with foliage as compared to bulbs stored without foliage (Pandey *et al*., 1992). In contrast the lowest dry matter found in bulbs stored in cemented room without foliage. Bulbs in mud room were better than Cemented room stored bulbs in dry matter content, while dry matter in bulbs kept under cold store was more than both Mud as well as Cemented room storages. Since, each storage condition is characterized by different temperature, considerable variations are reported under different storage conditions (Krawiec, 2002) with storage temperature resulting in increased dry matter losses (Tariq *et al.,* 2005).

Hadokova and Ito (1968) suggested that high soluble sugar content at harvest would be indicator of good keeping quality of onion bulbs. Cultivar having high dry matter content could be for longer storage period than those having low dry matter content (Toul and Pospisilova, 1968). Kodic (1971) found that the onion varieties with higher dry matter content stored well and retained their aroma better than those onion varieties having low dry matter. Onions which had their tops removed at harvest tend to have less dry matter than those on which the tops were retained (Nettles and Smith, 1971). Sprouting losses have been observed to be more in varieties with a low percentage of dry matter and TSS content (Sandhu *et al*., 1976).

Bajaj *et al*. (1980) reported that the average dry matter content of five white and seven red cultivars of onion on dry weight basis ranged from 10.66 to 14.8

per cent. Bajaj *et al*. (1980) reported that onion bulbs with higher levels of dry matter, total soluble solids, non-reducing sugars and phenolic content exhibited longer storage life. For better storage, the red cultivars with high level of dry matter, non-reducing sugars and phenolic constituents were found to be more suitable than white cultivars (Bajaj *et al*., 1981). Darbyshire and Henry (1981) observed that as the per cent dry weight of onion bulbs of nine cultivars increased, the fructose content also increased during storage.

Chang *et al*. (1987) reported that bulbs with high dry matter and pyruvic acid content have the better storage quality. Patil and Kale (1989) concluded that higher content of dry matter and TSS was associated with better keeping quality. Bulbs with high TSS, high dry matter, non-reducing sugar, thin neck and medium size of the bulbs were good storage quality of onion (Shaha *et al*., 1992).

Agic *et al*. (1997) observed that cultivars with a high dry matter percentage and those with a large number of dry scales showed potential for a longer storage period. The per cent dry matter and TSS increased during storage from 11.4 to 12.3 and 10.6 to 11.9, respectively, but reducing sugar content decreased from 3.47 to 2.35 per cent. However, the non-reducing sugar content of onion bulbs increased from 5.26 to 6.61 per cent during six months of storage (Patil and Kale, 1998).

Pramanick *et al*. (1989) found that SI-126 had the highest total soluble solids, dry matter percentage and ascorbic acid content makes suitable for storage. Bulbs of poor keeping varieties had low dry matter content, low TSS, high relative rate of loss and high moisture loss especially in the period immediately after harvest, which result in softening, shrivelling and loss of weight (Kallokumar *et al*., 1999).

2.10 Physiology of onion with respect to plant growth regulators

Knowledge of plant growth regulator (PGR) transport pathways has led to new opportunities to manipulate PGR levels within the plant. In plants, growth substances readily translocate from the upper part such as leaves to the lower part such as roots and stem. The pre-harvest chemical treatments of upper foliage with its translocation to lower parts are beneficial for the onion in terms of prolonging storage life. However, pre-harvest application has the drawback that unused chemical directly goes

to the soil and affects the quality and fertility of the soil. The various phases of plant growth are controlled by a balance of the level of endogenous hormones presented in the plant (Thomas and Rankin, 1982). Hemberg (1967) stated that the dormancy of onion is controlled by the interactions between different inhibitory and promoting substances. The role of endogenous growth regulators is well documented in diverse physiological processes, but there are many contradictory reports on the effects of both endogenous and exogenous substances.

2.11 Effect of chemicals on physico-chemical properties, shelf life and disease control of fruits and vegetables

2.11.1 Salicylic acid

Salicylic acid (SA) is considered to be a potent plant hormone (Raskin, 1992a) because of its diverse regulatory roles in plant metabolism (Popova *et al.,* 1997). Salicylic acid is an endogenous plant growth regulator of phenolic nature that possesses an aromatic ring with a hydroxyl group or its functional derivative. It possesses diverse physiological roles in plants and potentially alleviates the devastating effects generated by various biotic and abiotic stresses and plays a key role in the regulation of plant growth, development, interaction with other organisms (Raskin, 1992a,b; Yalpani *et al.,* 1994; Senaratna *et al.,* 2000). It is a well known naturally occurring immune signal in the induction of disease resistance response in plants (Denancé *et al*. 2013; Gimenez-Ibanez and Solano 2013; Yang *et al*. 2013). SA signaling system activates not only local resistance but also systemic acquired resistance (SAR) observed even in distal tissues. SAR is an SA-dependent heightened defense to a broad spectrum of pathogens that is activated throughout a plant following local infection (Liu *et al*. 2011a). In the past, exogenous application of SA and its derivatives such as acetyl salicylate and methyl salicylate were used to control post harvest diseases of fruits and vegetables by increasing the SAR (Babalar *et al.,* 2007). Many reports suggest that SA can be used as commercial application for maintaining post harvest quality to prolong shelf life of fruits, vegetables and ornamentals. Both pre- and post-harvest SA application in extending shelf life and maintaining quality of post harvest produce have been investigated and developed for commercial use. Dietary salicylates derived from fruit and vegetables are described as

bioactive compounds with heath care potential (Hooper and Cassidy, 2006) and are considered as generally recognized as safe (GRAS). It also effectively protects cell wall by decreasing the respiration rate mainly due to its negative effects on ACC, ACO, pectin methylesterase, cellulose and antioxidant enzymes leading to decrease in ethylene production and action (Mohammadreza and Morteza, 2010).

Javaheri *et al*. (2012) reported that tomato seedlings sprayed at two weeks after transplanting with different concentrations of salicylic acid at two week interval for five times. Plants treated with salicylic acid 10^{-6} M recorded significantly higher fruit yield (3059.5 g/bush) compared to non-treated plants (2220 g/bush). At 10^{-2}M concentration fruits had significantly higher vitamin C (32.5 mg per 100 g of fruit fresh weight), increased diameter of fruit skin (0.54 mm) more than two fold compared to control (0.26 mm) and high TSS (9.3^0B) as compared to non-treated plants (5.9^0B). These results suggest that foliar application of salicylic acid may improve quantity and quality of tomato fruits.

Supriya (2015) recorded that onion bulbs treated with Salicylic acid at 2 mM found to significantly lower PLW (14.70%), minimum respiration was observed in onion bulbs treated with SA 4 mM (16.00 ml CO_2/kg/h) and the minimum sprouting was noticed onion bulbs treated with 4 mM SA (3.70%).

Pineapple fruits treated with 5mM salicylic acid concentration for 15 minutes and stored at 10°C exhibited significant decrease tissue respiration rate, soluble solid content, titrable acidity, soluble sugar content and slowed degradation of starch. The activity of peroxidase, polyphenol oxidase, phenylalanine ammonia-lyase also decreased with this treatment. Salicylic acid treatment increased the activity of superoxide dismutase and ascorbate peroxidise along with extending the shelf life as compared to the untreated control (Lu *et al*., 2010).

In jujube fruit (*Ziziphus mauritiania* Lamk) vitamin C, total soluble solids (TSS), acidity, firmness and quality grade increased significantly by the SA (150 mg/L at 3 weeks before harvest) treatment either at harvest time or after cold storage. The percentage of fruit weight loss commercially unacceptable peel as well as, fruit browning index tended to decrease in SA spray (Al-Obeed *et al*., 2012).

Khademi and Ershadi (2013) found that post harvest treatment of peach fruits cv. Elberta with SA (2 mM) had positive effect on firmness, total phenolic contents and antioxidant capacity of fruits without any adverse influence on fruit taste and appearance. Pre storage treatment of Satsuma mandarin fruits with 2 mM SA showed decreased disease incidence of 10 per cent in first 50 days and 23.3 per cent in next 120 days of storage. In addition to increased fruit firmness, contents of H_2O_2 and some defense related metabolites enhanced storability of citrus fruit (Zhu *et al.,* 2016).

The effect of salicylic acid (SA) on strawberry (cv. Selva) fruit was studied by treating at 3 stages namely, vegetative stage (v), fruit development stage (F) and as postharvest treatment of fruits (P). When plants were treated with 2 mmol /L SA at F and P stage more than 30 per cent reduction in fruit ethylene production was observed compared to control fruits. SA at all concentrations effectively reduced fruit ethylene production, fungal decay and retained overall quality. Single stage treatment strategy of fruits with 2 mmol /L SA at postharvest stage was the most effective. Post-harvest treatment with 4 mmol /L SA slightly damaged the fruits and was less effective than 2 mmol /L in retaining fruit quality (Babalar *et al.*, 2007).

Amin *et al*. (2007) investigated that foliar application of salicylic acid (50, 100, 200 mg/l) on onion results in significant increase in growth characters, photosynthetic pigments content/ leaves, yield and its quality traits, total soluble sugars, total free amino acids, total phenols and total indoles. The lower and moderate concentrations (50 and 100 mg/l) were more effective than the higher ones (200 mg/l).

Yeganeh *et al*. (2013) studied effect of salicylic acid in table grapes cv. ‘Bidaneh Sefid’ both at pre and post harvest stages and found that SA significantly improved the post-harvest performance of berries in all studied traits *viz.* soluble solid content, dry matter, sugar/acid ratio and fruit overall quality. SA at 2 and 4 mM decreased water losses, fungal decay and rachis browning. Fruits treated at both pre and post harvest maintained better quality in comparison to fruits treated after harvest.

Post harvest treatment of Apple cv. Jonagold in SA solution (0,1.5, 3 mM) for 5 min resulted in retention of maximum fruit firmness, TSS, TA, peroxidase activity, ascorbic acid content and superoxide dismutase activity and reduced browning index, relative electrical conductance and weight loss compared to control (Kazemi *et al.*,

2011). Shafiee *et al.* (2010) found that pre harvest application salicylic acid (0.03 mM) along with nutrient solution in strawberry cv. Camarosa prevented fruits softening, decreased weight loss, decay and extended post harvest life. The authours opined that SA can be easily used instead of laborious postharvest treatments to improve strawberry fruit quality.

Yao *et al.* (2005) investigated the effect of pre harvest application of cherry fruits with SA (2 mM) and methyl jasmonate (0.2 mM) on cherry fruits to induce defense resistance system against post-harvest diseases and found promising measure for controlling post-harvest decays on a commercial scale. SA treated fruits possess direct fungi toxicity on *Monilinia fructicola* and inhibited mycelial growth, spore germination of the pathogen invitro. The fruit treated with MeJA (pre-harvest) expressed higher activity of β-1, 3 glucanase and PAL than fruit treated with SA and the control during the early storage time.

Pomegranate fruit were treated with salicylic acid (0.7, 1.4 or 2.0 mM) followed by storing fruits at 2^{o}C for 3 months. Fruits treated with SA (2 mM) resulted in reduced chilling injury, electrolyte leakage and maintenance of Vit C content (Sayyari *et al.,* 2009). SA treatments with concentrations of 2 and 4 mM significantly increased grape post-harvest life through maintaining the rachis conditions, reduced weight loss, increasing phenol content, improving plant defense mechanism and elimination or reduction of fungi contamination during storage. Thus, the treatments with SA may be an effective alternative to improve the post-harvest life and maintaining quality of grapes, with the addition of the benefit of improving phenolic content and composition, and reducing the rate of rachis browning during postharvest storage (Ranjbaran *et al.,* 2011).

Tsewang (2016) found that seedling dip followed by foliar spray of salicylic acid (2 mM) 60 and 90 days after transplanting in onion crop resulted in lower PLW and higher pungency. Foliar spray of salicylic acid (2 mM) 90 days after transplanting exihibited increased firmness of bulbs, higher yield, and lower respiration rate. Seedling dip followed by foliar spray of 2 mM salicylic acid at 90 DAT showed good sensory attributes with respect to texture, flavour and taste.

Xuang *et al*. (2001) found that the foliar application of salicylic acid at 1 mM increased bulb girth in garlic.

Krishna *et al*. (2011) found that both pre- and postharvest treatments of apple cv. 'Oregon Spur' with SA resulted in improvemed physico-chemical characteristics and reduced fruit infection percentage resulting in improved fruit quality and extended shelf life of apple fruits. Lolaei *et al.* (2012) found that both pre-harvest and post-harvest treatments of SA effectively increased the fruit quality of strawberry fruit during storage. Treated fruits exihibited higher titratable acidity, less weight loss, decay, higher vitamin C and redness in comparison to control. SA treatment delayed the onset of the climacteric peak of respiration and also inhibited respiration and ethylene production. SA affected on the quality of strawberry fruit and increased its store-keeping.

Alijo *et al*. (2015) conducted a study to know the effect of post harvest treatment of peach fruits cv. 'Elberta' with three different concentrations 0.5, 1 and 2 mM L^{-1} SA and three different concentrations 250, 500 and 750 ppm and cinnamon essential oil for 5 min at 25ºC. SA @ 2 mM was found to be effective in reducing the weight loss (1.89 %) along with improved quality parameters during of storage period.

Noor *et al*. (1998) reported that the bulbs treated with salicylic acid @ 800 to 1000 ppm recorded less moisture loss, delayed sprouting, rotting and maximum overall acceptability scores when compared to control.

2.11.2 Azoxystrobin

The Strobilurins are a group of broad-spectrum fungicides with non-toxic effects on humans or the environment. These compounds are active synthetic substances with a similar action to the natural strobilurin A (Anke *et al.,* 1977), and they are active against the major groups of plant pathogenic fungi. Azoxystrobin (Amistar 25 SC) is a potent strobilurin fungicide having novel biochemical mode of action (Hewitt, 1998). Its fungicidal activity results from the inhibition of mitochondrial respiration in fungi, which is achieved by the prevention of electron transfer between cytochrome b and cytochrome c (Becker *et al.,* 1981). The result of this activity is the cessation of normal energy production (ATP) within the cells,

which results in cell death. Evidence of this on fungi can be observed in spore mortality, mycelial collapse and inhibition of sporulation or disruption of other vital stages of fungal development (Harrisson and Tedford, 2002).

According to Supriya in the year (2015), foliar application of onion crop with Azoxystrobin (0.5ml/L) showed minimum rotting (7.8%) and maximum marketable yield. Tsewang (2016) found that foliar application of onion crop with 0.1 per cent azoxystrobin 60 and 90 DAT was found to be effective in controlling rotting and giving higher total phenolic content and foliar spray of azoxystrobin (0.1%) at 90 DAT resulted good quality bulbs interms of size, diameter, reduced sprouting and disease incidence.

The study of Srinivasan *et al*. (2014) on the performance of azoxystrobin tested against anthracnose and powdery mildew diseases of chilli confirms the efficacy of this chemical. In this study, azoxystrobin was sprayed in various doses (62.5, 125.0, 187.5 and 250.0 g *a.i* /ha) at fifteen days interval for three times starting from 35 days after planting. It was found that azoxystrobin at 250 g *a.i*/ha effectively controlled fruit rot and powdery mildew diseases of chilli. This treatment also recorded the highest fruit yield. Azoxystrobin did not induce any phytotoxic effect in chilli crop.

Anand *et al.* (2007) conducted a study to know the compatibility of *Pseudomonas fluorescens* (Pf1) with azoxystrobin at different concentrations *viz.,* 100, 150, 200, 250 and 300 ppm and revealed that the bacterium was compatible with all the concentrations tested, even at the maximum concentration of 300 ppm, its growth was unaffected. The field experiment revealed that the combined foliar application of Pf1 (2.5 kg ha-1) and azoxystrobin (250 ml ha^{-1}) reduced downy mildew as well as powdery mildew disease severities in cucumber more than azoxystrobin (250 and 500 ml ha^{-1}) alone. The Per cent Disease Index (PDI) of downy mildew recorded was only 2.22 and 1.00 and PDI of powdery mildew was 1.85 and 0.50 during the first and second seasons respectively. The treatment also recorded maximum fruit yield of 14.30 and 15.65 tonnes ha^{-1} for the first and second seasons, respectively. The combined application of both significantly increased the survival of Pf1 in the

phylloplane of cucumber crop. In addition, there was multifold increase in peroxidase, polyphenol oxidase, phenylalanine ammonia lyase, ß-1, 3 glucanase, chitinase and phenolics in plants.

Deidhiou *et al*. (2014) reported field testing of azoxystrobin (250g/L) and myclobutanyl (240 g/L) as the most effective fungicides to control anthracnose disease and extend shelf life of mango fruits. A single foliar spray of mango trees with myclobutanyl or two sprays with azoxystrobin reduced the disease incidence from 100 per cent to 30 per cent for fruits stored for 7 weeks while maintaining the fruit quality.

Pre-harvest spray of azoxystrobin (416.7 mg/L *a.i.*) improved post-harvest shelf-life of lettuce by reducing chlorophyll degradation, senescence and total polyphenol content which can be linked to less browning during storage (Bonasia *et al.,* 2013).

2.11.3 Cycocel (CCC)

Chloro coline chloride (CCC) belongs to quaternary ammonium compound groups of synthetic chemicals. Since its discovery in the 1960s, cycocel has become one of the most widely utilized commercial plant growth regulators in the world, because it exhibits low toxicity and exerts its effects on many crop plants. Cycocel retards stem extension without any physiological aberration. Application of this chemical neither suppresses the growth permanently nor causes any deleterious effect on the vigour of the treated plants.

Cycocel is the most active member of the new group of quaternary ammonium compounds and is anti-gibberellin in its action. Application of cycocel retarded shoot growth and reduced the internodal length and slowing down cell division or cell elongation in many crops. Reduction in leaf number and leaf area was reported due to cycocel application in several crop plants**.** Cycocel belongs to the group of quaternary ammonium compound, an anologue of chlorine, which is the most active compound. Pre-harvest spray of 1000 ppm cycocel recorded least per cent loss (10%) and better keeping quality of tomato compared to untreated tomato fruits (25%) (Bhujbal and Patil, 1978)

Foliar application of different growth regulators, cycocel at 1000 ppm recorded minimum loss in fresh weight and significantly longer post-harvest life (9.74 days) of cut 'Raktaganda' roses over control (7.40 days) (Chaobasingh and Bhattacharjee, 1998).

Foliar spray of at cycocel 500 ppm significantly increased the diameter, number of cloves per bulb and yield in garlic (Das *et al.*, 1980). Onion crop sprayed with cycocel @ 2500 ppm on 75 and 90 days after transplanting showed positive effect by decreasing rotting percentage when compared to control (Anonymous, 2004).

Singh (2011) conducted a field experiment to know the effect of foliar application of various treatments *viz.* potassium sulphate (0, 1 % and 2%), cycocel (0, 1000 and 1500 ppm) and benlate (0 and 500 ppm) on various morphological parameters and on post harvest life of ber, cultivar Banarasi Karaka. First application was given in month of September during blooming period followed by second application at pea stage of fruits. During storage of fruits a combination of (cycocel 1500ppm, potassium sulphate 2 per cent and benlate 500 ppm) significantly increased TSS and ascorbic acid content at different period of storage and maintained maximum level at 12 days of storage.

Kumara and Patil (2014) conducted a study to know effect of pre-harvest sprays of growth regulators and chemicals on storage life of garlic. Application of CCC (1000 ppm) + dithane M-45 (1000 ppm) showed maximum recovery of healthy cloves (41.04%) at the end of 180 days of storage.

An investigation was carried out by Gautam *et al.* (2014) to know the effect of clove weight and plant growth regulators on growth and yield of garlic cv. Agrifound Parvati. The treatment combination of clove weight 3.1-3.5 g and cycocel 1000 ppm gave the highest bulb yield per plot (3.79 kg) along with improved growth parameters.

Zinzala *et al.* (2017) conducted a field experiment to know the effect of foliar application of plant growth regulators on growth, yield and quality of garlic var. GG-3. The treatment cycocel 1000 mg/1 recorded maximum number of leaves per plant at 60 DAS (8.80) and 90 DAS (10.20 cm), highest fresh (32.39 g) and dry (12.39 g) bulb

weight, diameter of bulb (4.92 cm), number of cloves per bulb (19.52), maximum length of clove per bulb (3.06 cm), highest weight of clove per bulb (1.91 g), yield per plot (3.52 kg) and yield/ha (9.57 t) along with the maximum net return with BCR (3.94).

Ram *et al.* (2012) conducted a study to know effect of post harvest treatment of aonla cv. NA-6 with following treatments. Ventilated (0.5%) polyethylene bags (control packed), treatment with cycocel (100 ppm) + benlate (0.1%), treatment with cycocel (100 ppm) + benlate (0.1%) + packed in 0.50% ventilated polyethylene bags, treatment with maleic hydrazide (100 ppm) + benlate (0.1%), treatment with maleic hydrazide (100 ppm) + benlate (0.1%) and packed in 0.5 per cent ventilated polyethylene bags were considered for experiment. The result revealed that among different treatments, cycocel 100 ppm + benlate 0.1% bagged in polyethylene showed maximum retention of ascorbic acid content, maintaining higher amount of acids, tannins and least physiological loss in weight (PLW) with chlorophyll degradation at minimum levels. Similarly, the incidence of spoilage reduced during storage. The fruits treated with cycocel (100 ppm) + benlate (0.1%) followed by packing in polyethylene bags improved physico-chemical quality and shelf life of aonla under the agro-climatic conditions of Lucknow.

Singh *et al.* (2008) evaluated the effect of growth regulators on growth and yield of garlic and reported that the application of cycocel @ 600 ppm with 60 ppm NAA and 60 ppm ethrel resulted maximum plant height, stem diameter, number of leaves per plant, length and width of leaves, bulb size and bulb yield.

Memane *et al.* (2008) studied the effect of clove weight and plant growth regulators on growth and yield of garlic cv. GG-3. Cloves dipped in cycocel @ 1000 ppm and NAA @ 50 ppm recorded the maximum plant height. Dipping cloves in 1000 ppm of cycocel recorded maximum number of leaves per plant, weight of bulbs, weight of cloves, diameter of bulb, number of cloves per bulb, yield and TSS content when compared to control.

Gasti *et al.* (2011a) observed that spraying of garlic with different concentrations of cycocel at full vegetative growth *i.e.* 60 days after sowing. Highest bulb yield was recorded with mapiquat chloride at 175 ppm. Gasti *et al.* (2011b)

studied the effect of pre-harvest sprays of growth retardants on yield of onion. The results revealed that treatment with different concentrations of cycocel and mapiquat chloride sprayed at full vegetative growth *i.e.* 45 days after sowing. Mapiquat chloride @ 175 ppm gave a maximum bulb yield per hectare over control.

Sankar and Lawande (2011) studied the effect of pre-harvest sprays of growth retardants on growth and yield of garlic var. G-41 and the results revealed that treatment with Cycocel @ 6 ml/l applied as foliar spray at different growth stages though increased yield over control, it was non significant and there was no additional benefit of foliar application of cycocel.

Anbukkarasi *et al.* (2011) studied the effect of pre-harvest foliar sprays of growth regulator and fungicides on growth and yield of onion. The results revealed that treatment with Cycocel @ 200 ppm + Carbendazim @ 1000 ppm sprayed at 30 days before harvest recorded more number of leaves per plant, weight of bulb and bulb yield.

2.10.4 Sensory evaluation

Quality is a measure of degree of excellence or degree of acceptability of a product by the consumer. It is realized the acceptability of a product cannot be determined based on physical, chemical and microbiological criteria without conducting sensory evaluation (Joshi and Bushan, 2002). Hence, evaluation of sensory qualities is an important tool for deciding the consumer acceptability. Sensory characteristics of quality include appearance, texture, flavor, taste and overall acceptability.

Deidhiou *et al*. (2014) reported that field testing of azoxystrobin (250g/L) and myclobutanyl (240 g/L) extended the shelf life of mango fruits for 7 weeks while maintaining the fruit quality. Shafiee *et al*. (2010) observed that strawberry fruits dipped in salicylic acid solution at 2 mM concentration were found to have higher firmness than control.

The sensory evaluation of artificially cured bulbs showed better appearance, relatively bright and glossiness compared to the sun cured bulbs (Satish and Ranganna, 2002b).

Sonawane *et al*. (2016) noticed that foliar application of cycocel 1500 ppm to mango cv.Alphanso trees resulted in increased yield of 5291.67 Kg/ha along with obtaining maximum organoleptic score for colour, flavour and texture.

3. MATERIALS AND METHODS

The present investigation was carried out at College of Horticulture located in the main campus of University of Horticultural Sciences (UHS) Bagalkot, Karnataka; during *kharif* season of the year 2016-17. The details of material and methods used for the "Studies on field application of salicylic acid, azoxystrobin and cycocel on shelf life of onion cv. Arka Kalyan" the experimental design adapted and procedures followed for the statistical analysis of the experiment are outlined here.

3.1 Geographical location and climate

Bagalkot falls in the Northern Dry Zone (Zone-3) of Karnataka. The study area was located at 75° 42' East longitude and 16° 10' North latitude with an altitude of 542.00 m above Mean Sea Level (MSL). The district is grouped under arid and semi-arid region with mean annual rainfall of 517.3 mm and mean temperature of 32.6°C.

3.2 Experimental site

The experiment was carried out by raising onion crop at College of Horticulture, UHS main campus, Bagalkot. Soil of the research plot was analysed for the macro nutrients at the Department of Soil Science and Agricultural Chemistry, College of Horticulture, Bagalkot. Available nitrogen, phosphorus and potassium were found to be 280 to 560 N/kg/ha (medium), 50.27 kg/ha (medium) and 698.88 kg/ha (very high) respectively. The EC of the soil was 0.83 (medium salinity) and pH of the soil was found to be 7.72 (neutral). Further, this nutrient status of the soil was considered as the basis for the application of fertilizers to raise the crop

3.3 Varietal description

The variety Arka Kalyan was released from the IIHR Bangalore, Karnataka. It was developed through vigorous mass selection from IIHR-145, identified for IV, VI, VII and VIII zones during 1987. It is suitable for *kharif* season. Bulbs are globus shaped, average bulb weight is 130-180 grams with deep red coloured outer scales. The bulbs are pungent with TSS range of 11-13 per cent. The variety is moderately resistant

to purple blotch disease. The performance of the variety in storage is average. The average yield is 45 t /ha (Anon., 2012).

3.4 Experimental details

Detailed programme of research

Experiment:

Location	: COH, BAGALKOT
Experimental design	: RCBD
Plot size	: 1.8 m X 1.8 m
Number of treatments	: 12
Number of replications	: 3
Quantity of bulbs/ replication	: 12 kg/replication
Variety	: Arka Kalyan
Spacing	: 15 cm X 10 cm
Gross area	: 134.14 m^2 (0.033 acre)
Net area	: 116.64 m^2 (0.028 acre)

Treatment details

T_1 - Control

T_2 - Pre-harvest spray of salicylic acid (2 mM) at 60 + 90 DAT

T_3 - Seedling dip in salicylic acid (2 mM) + Pre-harvest spray of salicylic acid (2 mM) at 60 + 90 DAT

T_4 - Pre-harvest spray of azoxystrobin (0.1%) at 60 + 90 DAT

T_5 - Pre-harvest spray of salicylic acid (2 mM) and azoxystrobin (0.1%) at 60 + 90 DAT

T_6 - Seedling dip in salicylic acid (2 mM) + Pre-harvest spray of salicylic acid (2 mM) followed by foliar spray of azoxystrobin (0.1%) at 60 + 90 DAT

T_7 - Pre-harvest spray of cycocel 2500 ppm at 90 DAT

T_8 - Pre-harvest spray of salicylic acid (2 mM) at 60 + 90 DAT and foliar spray of cycocel 2500 ppm at 90 DAT

T_9 - Seedling dip in salicylic acid (2 mM) + Pre-harvest spray of salicylic acid (2 mM) at 60 + 90 DAT and foliar spray cycocel (2500 ppm) at 90 DAT

T_{10} - Pre-harvest spray of azoxystrobin (0.1%) at 60 + 90 DAT and foliar spray of cycocel (2500 ppm) at 90 DAT

T_{11} - Pre-harvest spray of salicylic acid (2mM) and azoxystrobin (0.1%) at 60 + 90 DAT followed by cycocel (2500 ppm) foliar spray at 90 DAT

T_{12}- Seedling dip in salicylic acid 2 mM + Pre-harvest spray of salicylic acid (2 mM) and azoxystrobin (0.1%) at 60 + 90 DAT followed by foliar spray of cycocel (2500 ppm) at 90 DAT

3.4.1 Cultural operations

The details of various cultural operations followed at the time of raising onion crop for research work are briefed here under.

3.4.1.1 Nursery operation

Around five raised nursery beds of size 4.0 m x 1 m were prepared on which seeds are sown thinly by maintaining spacing of about 2-3 cm between the seeds and row to obtain around 4000 to 5000 seedlings.

3.4.1.2 Preparation of experimental plots

The land was ploughed thoroughly, clods were broken and the soil was brought to a fine tilth. The experimental plots of size 1.8x1.8 square meter were prepared. 3 rows each consisting of 12 plots, were laid down (Fig.1).

Plate 1. General view of the experimental plot

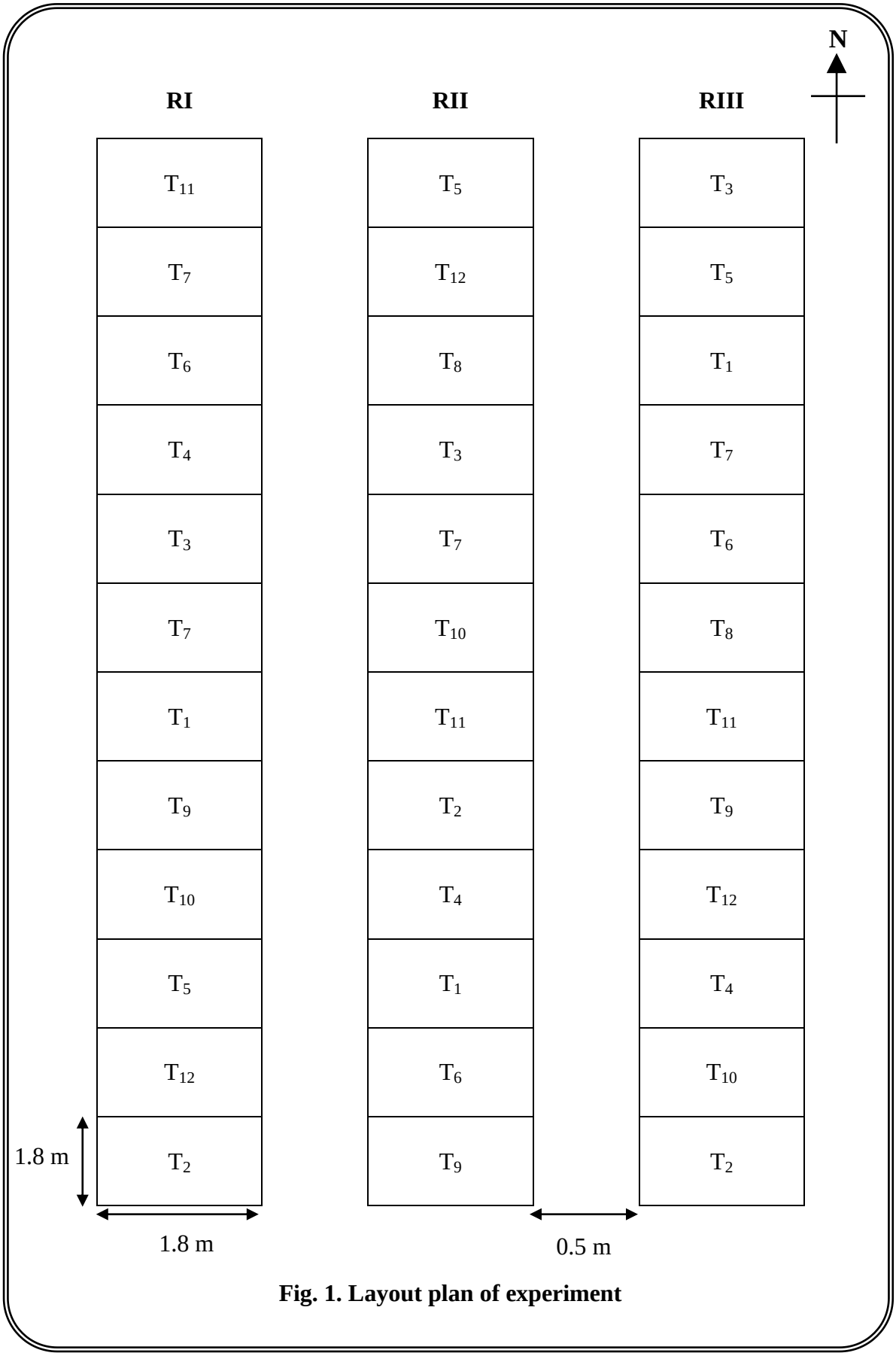

Fig. 1. Layout plan of experiment

3.4.1.3 Transplanting

Healthy and uniform seedlings were transplanted during early morning period. The seedlings were transplanted at a spacing of 10 cm x 15 cm. A light irrigation was given immediately after transplanting.

3.4.1.4 Application of manures and fertilizers

A well decomposed farm yard manure @ 25 t/ha was applied at the time of land preparation. A recommended dose of 125:75:125 kg N, P_2O_5 and K_2O per ha (Anon., 2013) was applied in two splits, *i.e.*, 50 per cent N and full dose of P and K as a basal dose in the form of urea, super phosphate and murate of potash respectively. The remaining 50 per cent of N was applied after six weeks of transplanting. The actual quantity of fertilizers used was based on initial nutrient status of soil.

3.4.1.5 After care

Regular hand weeding was carried out to keep the plot free from weeds. Irrigation was given at weekly interval throughout the entire period of crop cultivation. All the plant protection measures and earthling up was followed as per the recommendations of package of practices (Anon., 2013).

3.4.1.6 Preparation of spray solutions for pre-harvest treatments

Salicylic acid being sparingly soluble in water was first dissolved in little quantity of ethanol and then by making up the volume with water. The rest of the chemicals like azoxystrobin and cycocel were prepared by dissolving the required quantities in known volume of water to obtain the required concentrations. A spray volume of 2 liters was prepared for each replication. The solutions were sprayed uniformly and enough care was taken to avoid drifting of chemicals to other plots by erecting temporary barriers around the plot. The solutions were sprayed using Knap sack sprayer to onion foliage in accordance with the experimental treatments.

3.4.1.7 Harvesting

The crop was harvested at maturity *i.e.*, 120 days after transplanting (DAT) when 50 per cent of the plants showed drying and falling of their tops. The plants were

Plate.2. Transplanting

Plate 3a. Chemicals used for foliar spray

Plate 3b. Seedling dip with salicylic acid

Plate 3c. Imposition of pre-harvest foliar sprays

Plate 4. Experimental plot at the time of harvesting

Plate 5a. Harvesting

Plate 5b. Field curing

Plate 5c. Neck cutting

Plate 6. Picture showing storage of onions in gunny bags

pulled along with leaves and kept for curing for a week under open condition. Then the foliages were cut with sharp clean knife leaving about 2.5 cm top above the bulb. These bulbs were then shade cured for 15 days.

3.4.1.8 Storage

The cured onion bulbs were sorted out by removing sprouted and damaged bulbs and 12 kg healthy and uniform bulbs from each treatment were packed in thin gunny bag of size 45x60 cm^2 and kept in clean empty room for storage studies.

3.5 Observations recorded

The following observations were recorded on bulbs during the period of storage. Initial observations were recorded before keeping the bulbs for storage. Physiological loss in weight per cent, sprouting percentage, rotting percentage, per cent moisture content, per cent dry matter, TSS content, Incidence of black mould (%), bulb firmness (N), colour of the bulbs and per cent marketable bulbs were recorded at monthly interval for a storage duration of 4 months. The details of the methodology adopted for recording these observations during experimentation are described below.

3.5.1 Field parameters

3.5.1.1 Yield (t/ha), number of bulbs/kg and bulb diameter (mm)

Yield and number of bulbs per kg were observed using weighing balance and diameter was recorded using digital vernier caliper (Make: Seiko Instrument Inc., Model: CD-6 ASX).

3.5.2 Physical parameters

Initially 12 kg bulbs were selected in each treatment. These bulbs were used each time for recording rotting, sprouting percentage and per cent black mould incidence.

3.5.2.1 Sprouting percentage

For determining the sprouting percentage on stipulated days after storage, the bulbs showing sprout were separated from the lot and weighed on an electronic balance. The sprouting percentage, which indicated the weight of the bulbs sprouted on 30, 60, 90 and 120 DAS was calculated by using the formula given below.

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

3.5.2.2 Rotting percentage

Rotting percentage was determined by separating the rotten bulbs from the lot and weighed on an electronic balance. The rotting percentage, which indicated the weight of the bulbs rotten at 30, 60, 90 and 120 DAS was calculated by using the formula given below.

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

3.5.2.3 Incidence of black mould (%)

The incidence of black mould which is a major storage disease caused by *Apergillus niger* was recorded at monthly interval up to 4 months. The incidence of black mould was expressed in percentage.

3.5.2.4 Physiological loss in weight (%)

In each replication, 25 bulbs were earmarked to record the PLW. The marked bulbs in each replication of the respective treatment were weighed individually at the beginning of storage to record the initial weight. Subsequently at monthly interval the bulbs were weighed again. The cumulative losses in weight of bulbs were calculated and expressed as per cent physiological loss in weight using the formula given below.

$$\text{Physiological loss in weight (\%)} = \frac{\text{P0} - \text{P1 or P2 or P3 or P4}}{\text{P0}} \times 100$$

Where,

P_o= initial weight P_1= weight after 30 days

P_2= weight after 60 days P_3= weight after 90 day

3.5.2.5 Respiration rate (ml CO_2/kg/hr)

Respiration rate was measured with a CO_2 gas analyzer (Make: Quantek Instruments, Model: 902 D Dual Trak) in static method. The bulbs were weighed and placed in a hermetically sealed container of 1325 ml capacity for 45 minutes. At the end of incubation period, gas sample was drawn from the head space using a gas tight syringe and injected into the CO_2 gas analyzer. The time allowed for change in CO_2 gas concentration in the head space of the sample container was recorded in hour. The respiration rate of the bulbs was calculated using the following formula and expressed as ml CO_2/kg/hr.

$$\text{Respiration rate (\%)} = \frac{\text{CO2 concentration x volume of container (ml)}}{\text{100 x weight of the tissue (kg) x time (g)}} \times 100$$

3.5.2.6 Moisture content (%)

Moisture content was determined using the moisture analyzer (Make: RADWAG Wagi Elektroniczne, Model: MAC 50) which gives the final moisture content in percentage. Randomly selected bulbs from each treatment were cut into small pieces with the help of stainless steel knife and a known weight of 2 g sample were kept for moisture analysis using moisture analyzer.

3.5.2.7 Per cent 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 55°C temperature till a constant weight was obtained. The per cent dry matter was calculated by the following formula.

$$\text{Per cent dry matter (\%)} = \frac{\text{Dry weight}}{\text{Fresh weight}} \times 100$$

3.5.2.8 Firmness of the bulb (N)

Bulb firmness was recorded using TA-XT-Plus texture analyser (Stable Micro Systems, London, England). Using shearing probe (blade set. After removing the scales at two equatorial sites a 10 mm plunger tip was used to measure the bulb firmness. The force required to shear the bulb was recorded. Readings were expressed in Newton (N). Data was recorded initially and subsequently at monthly intervals till the end of experiment.

3.5.2.9 Marketable bulbs (%)

At the end of each storage period (30, 60, 90 and 120 DAS), the rotten 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.

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

3.5.3 Chemical parameters

3.5.3.1 Total phenol content (mg/100g)

Total phenol in the sample was estimated as per the Folin ciocalteau reagent (FCR) method (Sadasivam and Manickam, 2005). A sample of 0.5g of fresh tissue was taken and ground in 10 ml of 80 per cent ethanol with the help of pestle and mortar. The solution was filtered using filter paper and the filtrate was allowed to evaporate. Then, to that filtrate, 5ml of distilled water is added. From that filtrate, 0.5 ml solution was taken in a test tube to which 2.5 ml of distilled water, 1 ml FCR reagent and 2 ml of sodium carbonate were added and boiled in water bath for 10 minutes. Then, the contents of the test tube were cooled and the absorbance was measured at 650 nm by

using spectrophotometer. The total phenol content was calculated with the help of standard graph and expressed in mg per g of fresh weight.

3.5.3.2 Pyruvic acid (µmol/g)

Pyruvic acid present in the sample was estimated as per the procedure given by Ketter and Randle (1998). DNPH (2,4-dinitrophenylhydrazine) solution of 0.0125 per cent was prepared by dissolving 0.1625 g of wet DNPH powder in 1000 ml 2N HCl. One ml sample of diluted, filtered homogenate was added to 1 ml of a 0.0125 per cent solution of DNPH in a test tube. After keeping test tube for 15 min in a water bath at 37˚C, 5 ml of 0.6 N NaOH was added and absorbance was measured using spectrophotometer at 420 nm. A graph was plotted from the standards prepared by sodium pyruvate and then the concentration of pyruvic acid present in the sample was calculated by using the following formula.

µmoles of pyruvate/g tissue = µmoles/ml (read from standard curve) × Total dilution

3.5.3.3 Total soluble solids (TSS °B)

The juice extracted by squeezing the homogenized bulb scales through muslin cloth was used to measure the TSS. It was determined by using ERMA hand refractometer, replicated three times.

3.5.4 Sensory evaluation

Sensory evaluation of bulbs was carried out by a panel of 6 semi-trained judges at monthly intervals from the beginning of storage up to 4 months. The sensory characters *viz.*, skin color, texture, flavour and taste and overall acceptability were evaluated on a 9 point hedonic scale using the score card mentioned below. The mean of scores given by the judges were used for statistical analysis.

9 point hedonic scale	Colour	Texture	Taste and flavour	Overall acceptability
Sample A				
Sample B				
Sample C				
Sample D				
Sample E				
Sample F				
Sample G				
Sample H				
Sample I				
Sample J				

	Scale
9	like extremely
8	like very much
7	like moderately
6	like slightly
5	neither like nor dislike
4	dislike slightly
3	dislike moderately
2	dislike very much
1	dislike extremely

3.6 Stastical analysis

Statistical analysis was perfomed using Web Agri Stat Package (WASP) version 2.0 (Jangam and Thali, 2010). All the data collected were analysed by one way analysis of variance (ANOVA). Significant differences among means at p=0.05 were determined by post doc tests using Duncan multiple range test.

4. EXPERIMENTAL RESULTS

The present investigation entitled “Field application of salicylic acid, azoxystrobin and cycocel on shelf life of onion cv. Arka Kalyan” was conducted at College of Horticulture, Bagalkot (University of Horticultural Sciences, Bagalkot) during 2016-17. The bulbs imposed with various pre-harvest foliar sprays were stored under ambient conditions for 4 months. The behaviour of bulbs on various physiological, physico-chemical and organoleptic changes during storage was observed and recorded at monthly interval for up to 4 months. The results obtained from the investigation are presented in this chapter.

4.1 Yield (t/ha), number of bulbs/kg and bulb diameter (mm)

The data on yield of onion bulb cv. Arka Kalyan as influenced by field application of salicylic acid (SA), azoxystrobin and CCC is presented in Table 1. The treatments resulted in slight significant differences for yield trait. Maximum yield was recorded in the treatment T_{11} (Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT) (48.56 t/ha) and it was on par with the treatments T_5 (48.31 t/ha). Significantly minimum yield (44.24 t/ha) over all other treatments was observed in treatment T_{12} (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT).

The data presented on number of bulbs per kg of onion (var. Arka Kalyan) exhibited significant differences among the treatments (Table 1). Numerically maximum number of bulbs per kg (14.33) was obtained in the treatment T_8 (Pre-harvest spray of salicylic acid @ 2 mM at 60 + 90 DAT and foliar spray of CCC 2500 ppm 90 DAT) and it differed significantly with T_5 (14.00), T_6 (13.33), T_7 (13.67) and T_9 (13.00). In contrast, the treatment T_{12} (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) recorded minimum number of bulbs per kg (10.67).

Maximum bulb diameter of 58.62 mm was observed in the treatment T_{12} (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid @ 2 mM

Table 1: Effect of field application of salicylic acid, azoxystrobin and cycocel on yield (t/ha), number of bulbs/kg and bulb diameter (mm) of onion cv. Arka Kalyan

Treatments	Parameters		
	Yield (t/h)	Number of bulbs/kg	Diameter (mm)
T_1	47.10^{c}	11.00^{e}	58.29^{ab}
T_2	47.93^{b}	11.33^{e}	57.51^{abc}
T_3	44.84^{f}	11.67^{cde}	57.05^{abcd}
T_4	47.32^{c}	11.33^{cd}	57.97^{abc}
T_5	48.31^{ab}	14.00^{a}	55.64^{de}
T_6	45.52^{e}	13.33^{abc}	56.39^{cde}
T_7	47.43^{c}	13.67^{ab}	56.51^{cde}
T_8	48.07^{b}	14.33^{a}	55.15^{e}
T_9	46.20^{d}	13.00^{abcd}	56.65^{bcde}
T_{10}	48.10^{b}	12.00^{cde}	56.89^{bcd}
T_{11}	48.56^{a}	12.00^{bcde}	57.02^{abcd}
T_{12}	44.24^{g}	10.67^{e}	58.62^{a}
Mean	**46.97**	**12.36**	**56.97**
S. Em±	0.14	0.68	0.56
CD@5%	**0.42**	**2.00**	**1.64**

Note: Values with the same superscripts in same column are not significantly different by Duncan Multiple Range Test at $p \leq 0.05$.

T_1 – Control	T_7 – Pre-harvest spray of CCC 2500 ppm at 90 DAT
T_2 – Pre-harvest spray of SA (2 mM) at 60 + 90 DAT	T_8 – Pre-harvest spray of SA (2 mM) at 60+90 DAT + CCC 2500 ppm at 90 DAT
T_3 – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) at 60 + 90 DAT	T_9 – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) at 60 + 90 DAT+CCC 2500 ppm at 90 DAT
T_4 – Pre-harvest spray of azoxystrobin (0.1%) at 60 + 90 DAT	T_{10} – Pre-harvest spray of azoxystrobin (0.1%) + CCC 2500 ppm at 90 DAT
T_5 – Pre-harvest spray of SA (2 mM) + zoxystrobin (0.1%) at 60+90 DAT	T_{11} – Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT + CCC 2500 ppm at 90 DAT
T_6 – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT	T_{12} – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT + CCC 2500 ppm at 90 DAT

Plate 7. Appearance and physical condition of onions under different treatments just before storage

and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT). In contrast, minimum bulb diameter noticed in the treatment T_8 (Pre-harvest spray of salicylic acid @ 2 mM at 60 + 90 DAT and foliar spray of CCC 2500 ppm 90 DAT) (55.15 mm).

4.2 Physiological loss in weight (PLW %)

It is revealed from Table-2 that there exists a significant difference in PLW of onion bulbs at different storage interval as influenced by field application of salicylic acid, azoxystrobin and cycocel. Irrespective of treatments imposed, an increase in PLW of stored onion bulbs was noticed with mean values varying from 4.58 per cent to 21.85 per cent during storage period of 120 days.

After 30 days of storage, the treatment T_{11} (Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) (3.80%) exhibited least PLW which was on par with treatments T_6 (4.04%), T_5 (4.28%), T_9 (4.09%) and T_2 (4.33%). On the other hand, treatment T_1 (Control) exhibited highest PLW (6.04%) and it was significantly followed by treatment T_{10} (Pre-harvest spray of azoxystrobin (0.1%) at 60 + 90 DAT and foliar spray CCC 2500 ppm 90 DAT) (5.45%).

At 60 DAS, the treatment T_{11} (Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) (10.29%) continued to show least PLW followed significantly by treatments T_9 (10.40%) and T_6 (10.99%). However, the treatment T_1 (Control) continued to record significantly maximum PLW (15.28%) over all the treatments.

The same trend maintained at 90 DAS with the treatment T_{11} (Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) (14.10%) remaining effective with significantly minimum PLW over all other treatments. But, significantly higher PLW was observed in treatment T_1 (Control) (21.29%).

Even after 120 DAS, the treatment T_{11} (Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar

Table 2: Effect of field application of salicylic acid, azoxystrobin and cycocel on PLW (physiological loss in weight %) of onion cv. Arka Kalyan

Treatments	PLW (%)				Mean
	Storage (Days)				
	30	60	90	120	
T_1	6.04^{a}	15.28^{a}	21.29^{a}	26.15^{a}	17.19
T_2	4.33^{de}	12.54^{bcd}	17.21^{c}	21.01^{d}	13.76
T_3	4.41^{cd}	11.37^{def}	15.72^{e}	20.23^{e}	12.93
T_4	5.01^{bc}	13.41^{b}	18.23^{b}	24.08^{b}	15.18
T_5	4.28^{de}	12.08^{bcde}	16.33^{d}	20.13^{e}	13.09
T_6	4.04^{de}	10.99^{ef}	15.14^{e}	19.55^{e}	12.43
T_7	4.61^{cd}	11.68^{cdef}	17.28^{c}	24.41^{b}	14.49
T_8	4.45^{cd}	11.97^{bcde}	16.71^{cd}	23.12^{c}	14.06
T_9	4.09^{de}	10.40^{f}	16.35^{d}	22.77^{c}	13.40
T_{10}	5.45^{ab}	12.96^{bc}	17.18^{c}	23.09^{c}	14.67
T_{11}	3.80^{e}	10.29^{f}	14.10^{f}	17.76^{f}	11.62
T_{12}	4.49^{cd}	12.00^{bcde}	15.11^{e}	19.93^{e}	12.88
Mean	**4.58**	**12.08**	**16.72**	**21.85**	**13.81**
S. Em±	0.20	0.48	0.20	0.26	0.29
CD@5%	**0.60**	**1.45**	**0.61**	**0.75**	**0.85**

Note: Values with the same superscripts in same column are not significantly different by Duncan Multiple Range Test at $p \leq 0.05$.

T_1 – Control	T_7 – Pre-harvest spray of CCC 2500 ppm at 90 DAT
T_2 – Pre-harvest spray of SA (2 mM) at 60 + 90 DAT	T_8 – Pre-harvest spray of SA (2 mM) at 60+90 DAT + CCC 2500 ppm at 90 DAT
T_3 – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) at 60 + 90 DAT	T_9 – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) at 60 + 90 DAT+CCC 2500 ppm at 90 DAT
T_4 – Pre-harvest spray of azoxystrobin (0.1%) at 60 + 90 DAT	T_{10} – Pre-harvest spray of azoxystrobin (0.1%) + CCC 2500 ppm at 90 DAT
T_5 – Pre-harvest spray of SA (2 mM) + zoxystrobin (0.1%) at 60+90 DAT	T_{11} – Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT + CCC 2500 ppm at 90 DAT
T_6 – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT	T_{12} – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT + CCC 2500 ppm at 90 DAT

spray 90 DAT) showed the least PLW (17.76%) and treatment T_1 (Control) exhibited higher PLW (26.15%). These two treatments differed significantly over rest of the treatments.

4.3 Respiration rate (ml CO_2/kg/h)

Data pertaining to respiration rate of onion cv. Arka Kalyan as influenced by field application of SA, azoxystrobin and CCC during prolonged storage of 120 days is presented in the Table 3. Respiration rate of the onion bulbs increased over the storage period and it is clearly seen from the table mean which ranges between 12.55 ml CO_2/kg/h and 20.02 ml CO_2/kg/h. The significant differences were noticed among the treatments.

Initially slight difference in rate of respiration was observed among the stored onion bulbs and least respiration was exhibited by the treatment T_9 (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid @ 2 mM at 60 + 90 DAT) (11.25 ml CO_2/kg/h) which was on par with treatments T_6 (11.52 ml CO_2/kg/h), T_8 (11.53 ml/CO_2/kg/h**),** T_5 (11.64 ml CO_2/kg/h) and T_3 (12.02 ml CO_2/kg/h**)**. On contrary, significantly increased rate of respiration was noticed in treatment T_1 (Control) (14.81 ml CO_2/kg/h) followed non-significantly by T_4 (13.74 ml CO_2/kg/h).

After 30 days of storage, the treatment T_6 (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid @ 2 mM followed by foliar spray of azoxystrobin @ 0.1% at 60 + 90 DAT) showed reduced respiration rate (12.22 ml CO_2/kg/h) which was found to be on par with the treatment T_9 (12.44 ml CO_2/kg/h) and T_5 (12.81 ml/CO_2/kg/h). However, the treatment T_1 (control) (16.67 ml CO_2/kg/h) showed significantly higher rate of respiration over all other treatments.

At 60 days of storage, the treatment T_2 (Pre-harvest spray of salicylic acid @ 2 mM at 60 + 90 DAT) (15.07 ml CO_2/kg/h) was found to record significantly minimum respiration rate and it was on par with the treatments T_9 (15.21 ml CO_2/kg/h), T_3 (15.30 ml CO_2/kg/h), T_{11} (15.95 ml CO_2/kg/h), T_6 (16.29 ml CO_2/kg/h) and T_8 (16.64 ml CO_2/kg/h). The enhanced rate of respiration on the other hand, was noticed in treatment T_1 (Control) (20.25 ml CO_2/kg/h) followed non-significantly by T_4 (18.99 ml CO_2/kg/h), T_{12} (17.93 ml CO_2/kg/h) and. T_{10} (17.78 ml CO_2/kg/h).

Table 3: Effect of field application of salicylic acid, azoxystrobin and cycocel on respiration rate (ml CO_2/kg/h) of onion (cv.Arka Kalyan) stored under ambient condition

Treatments	Respiration rate (ml CO_2/kg/h)					Mean
	Storage (Days)					
	Initial	30	60	90	120	
T_1	14.81^{a}	16.67^{a}	20.25^{a}	21.84^{a}	23.14^{a}	19.34
T_2	12.90^{cd}	13.60^{efg}	15.07^{f}	17.90^{ef}	19.29^{efg}	15.75
T_3	12.02^{ef}	13.18^{fgh}	15.30^{f}	17.22^{gh}	18.74^{fg}	15.29
T_4	13.74^{b}	15.40^{b}	18.99^{ab}	19.50^{b}	21.47^{b}	17.82
T_5	11.64^{ef}	12.81^{ghi}	17.30^{cde}	17.96^{ef}	18.65^{fg}	15.67
T_6	11.52^{ef}	12.22^{i}	16.29^{def}	17.64^{fg}	19.18^{efg}	15.37
T_7	12.83^{cd}	14.77^{bc}	17.39^{cde}	19.31^{b}	20.81^{bc}	17.05
T_8	11.53^{ef}	13.78^{def}	16.64^{cdef}	18.40^{de}	20.65^{bcd}	16.20
T_9	11.25^{f}	12.44^{hi}	15.21^{f}	18.09^{ef}	19.92^{cde}	15.38
T_{10}	13.17^{bc}	14.29^{cde}	17.78^{bcd}	19.01^{bc}	20.44^{bcd}	16.93
T_{11}	12.30^{de}	13.45^{efg}	15.95^{ef}	16.80^{h}	18.35^{g}	15.37
T_{12}	12.90^{cd}	14.65^{bcd}	17.93^{bc}	18.74^{cd}	19.62^{def}	16.75
Mean	**12.55**	**13.95**	**17.00**	**18.53**	**20.02**	**16.41**
S. Em±	0.27	0.30	0.54	0.18	0.36	0.33
CD@5%	**0.81**	**0.90**	**1.59**	**0.54**	**1.10**	**0.99**

Note: Values with the same superscripts in same column are not significantly different by Duncan Multiple Range Test at $p \leq 0.05$.

T_1 – Control	T_7 – Pre-harvest spray of CCC 2500 ppm at 90 DAT
T_2 – Pre-harvest spray of SA (2 mM) at 60 + 90 DAT	T_8 – Pre-harvest spray of SA (2 mM) at 60+90 DAT + CCC 2500 ppm at 90 DAT
T_3 – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) at 60 + 90 DAT	T_9 – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) at 60 + 90 DAT+CCC 2500 ppm at 90 DAT
T_4 – Pre-harvest spray of azoxystrobin (0.1%) at 60 + 90 DAT	T_{10} – Pre-harvest spray of azoxystrobin (0.1%) + CCC 2500 ppm at 90 DAT
T_5 – Pre-harvest spray of SA (2 mM) + zoxystrobin (0.1%) at 60+90 DAT	T_{11} – Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT + CCC 2500 ppm at 90 DAT
T_6 – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT	T_{12} – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT + CCC 2500 ppm at 90 DAT

At the end of storage for 90 days, the least respiration was noticed in treatment T_{11} (Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) (16.80 ml CO_2/kg/h) and it was on par with treatment T_3 (17.22 ml/CO_2/kg/h). The treatment T_1 (Control) (21.84 ml CO_2/kg/h) continued to show increase in the rate of respiration.

With the advancement in the storage up to 120 days, a significantly low respiration was noticed in treatment T_{11} (Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) (18.35 ml CO_2/kg/h) followed by T_5 (18.65 ml CO_2/kg/h), T_3 (18.74 ml CO_2/kg/h), T_6 (19.18 ml CO_2/kg/h) and T_2 (Pre-harvest spray of salicylic acid @ 2 mM at 60 + 90 DAT) (19.29 ml CO_2/kg/h). The treatment T_1 (Control) (23.14 ml CO_2/kg/h) was found continuously showing high rate of respiration.

4.4 Sprouting (%)

The data given in Table-4 represents the sprouting of onion cv. Arka Kalyan during storage period of 120 days as influenced by field application of salicylic acid, azoxystrobin and cycocel. In all the treatments, sprouting increased with increase in the storage period and significant differences were noticed among the treatments at all the stages of storage.

In the first 30 days of storage, the treatment T_{12} (Seedling dip in SA @ 2 mM + pre-harvest spray of SA @ 2mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by cycocel 2500 ppm foliar spray at 90 DAT) was seen effective in controlling sprouting (1.16%) followed by the treatment T_{11} (1.42%). On the contrary, treatment T_1 (Control) (3.94%) exhibited significantly maximum sprouting.

After 60 DAS the treatment T_{12} (Seedling dip in SA @ 2 mM + pre-harvest spray of SA @ 2mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by cycocel 2500 ppm foliar spray at 90 DAT) recorded significantly minimum sprouting (1.93%) and was on par with the treatments T_{11} (2.47%) and T_6 (2.72%). However, maximum sprouting was noticed in the onions of treatment T_7 (pre-harvest spray of CCC 2500 ppm at 90 DAT) (5.99%) which was on par with treatment T_1 (control) (5.92%).

Table 4: Effect of field application of salicylic acid, azoxystrobin and cycocel on sprouting (%) of onion cv. Arka Kalyan

Treatments	Sprouting (%)				Mean
	Storage (Days)				
	30	60	90	120	
T_1	3.94^{a}	5.92^{a}	9.43^{a}	10.93^{a}	7.56
T_2	2.62^{d}	3.78^{bc}	5.11^{d}	7.10^{c}	4.65
T_3	2.38^{d}	3.48^{cd}	4.62^{e}	7.07^{c}	4.39
T_4	1.91^{e}	3.08^{cde}	4.47^{ef}	5.84^{d}	3.83
T_5	1.68^{ef}	2.91^{cde}	4.23^{fg}	5.37^{d}	3.55
T_6	1.72^{ef}	2.72^{def}	4.00^{gh}	5.70^{d}	3.65
T_7	3.48^{b}	5.99^{a}	7.63^{b}	9.12^{b}	6.56
T_8	3.39^{bc}	4.50^{b}	7.33^{c}	8.32^{b}	5.89
T_9	1.82^{e}	2.90^{cde}	3.84^{h}	5.30^{d}	3.47
T_{10}	3.03^{c}	4.47^{b}	5.22^{d}	6.91^{c}	4.91
T_{11}	1.42^{fg}	2.47^{ef}	3.07^{i}	4.32^{e}	2.82
T_{12}	1.16^{g}	1.93^{f}	2.63^{j}	3.30^{f}	2.26
Mean	**2.38**	**3.68**	**5.13**	**6.61**	**4.45**
S. Em±	0.13	0.31	0.09	0.30	0.21
CD@5%	**0.39**	**0.92**	**0.28**	**0.91**	**0.63**

Note: Values with the same superscripts in same column are not significantly different by Duncan Multiple Range Test at $p \leq 0.05$.

T_1 – Control	T_7 – Pre-harvest spray of CCC 2500 ppm at 90 DAT
T_2 – Pre-harvest spray of SA (2 mM) at 60 + 90 DAT	T_8 – Pre-harvest spray of SA (2 mM) at 60+90 DAT + CCC 2500 ppm at 90 DAT
T_3 – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) at 60 + 90 DAT	T_9 – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) at 60 + 90 DAT+CCC 2500 ppm at 90 DAT
T_4 – Pre-harvest spray of azoxystrobin (0.1%) at 60 + 90 DAT	T_{10} – Pre-harvest spray of azoxystrobin (0.1%) + CCC 2500 ppm at 90 DAT
T_5 – Pre-harvest spray of SA (2 mM) + zoxystrobin (0.1%) at 60+90 DAT	T_{11} – Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT + CCC 2500 ppm at 90 DAT
T_6 – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT	T_{12} – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT + CCC 2500 ppm at 90 DAT

At 90 days after storage, the treatment T_{12} (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) recorded minimum sprouting (2.63%), whereas the treatment T_1 (control) exhibited pronounced sprouting (9.43%).

At the end of 120 DAS, least sprouting was observed in the treatment T_{12} (Seedling dip in SA @ 2 mM + pre-harvest spray of SA @ 2mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray at 90 DAT) (3.30%) and it differed significantly over rest of the treatments. The treatment T_1 (control) continued to show maximum sprouting (10.93%).

4.5 Rotting (%)

The data depicting the influence of field application of salicylic acid, azoxystrobin and cycocel on rotting of onion cv. Arka Kalyan is presented in the Table 5. Irrespective of treatments, loss of bulbs due to rotting increased with an increase in storage duration. This is witnessed from the mean per cent rotting which varied from 1.33 per cent to 5.21 per cent. The observations showed significant differences among the treatments.

In the first 30 DAS, the treatment T_5 (Pre-harvest spray of SA @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT) (0.72%) with minimum rotting was found to be on par treatments T_4 (1.14%), T_8 (0.80%), T_{10} (1.08%) and T_{11} (0.96%). On contrary, maximum rotting was noticed in treatment T_1 (Control) (2.58%).

At 60 DAS, the treatment T_5 (Pre-harvest spray of SA @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT) with least rotting of about 1.39 per cent was on par with the treatments T_{11} (1.51%) and T_8 (1.78%). The treatment T_1 (Control) continued show increased rotting (4.79%) and it differed significantly over all other treatments.

At 90 days, the treatment T_5 (Pre-harvest spray of SA @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT) (2.33%) had minimum rotting percentage and

Table 5: Effect of field application of salicylic acid, azoxystrobin and cycocel on rotting (%) of onion cv. Arka Kalyan

Treatments	Rotting (%)				Mean
	Storage (Days)				
	30	60	90	120	
T_1	2.58^{a}	4.79^{a}	8.30^{a}	12.69^{a}	7.09
T_2	1.41^{bc}	2.84^{cd}	4.11^{c}	5.12^{cd}	3.37
T_3	1.58^{b}	3.31^{bc}	4.04^{c}	5.32^{c}	3.56
T_4	1.14^{cde}	2.16^{ef}	3.01^{e}	4.04^{f}	2.59
T_5	0.72^{e}	1.39^{h}	2.33^{f}	3.05^{g}	1.87
T_6	1.48^{bc}	2.52^{de}	3.96^{c}	5.41^{c}	3.34
T_7	1.32^{bcd}	2.76^{cd}	3.82^{cd}	4.32^{ef}	3.06
T_8	0.80^{e}	1.78^{fgh}	2.51^{f}	3.40^{g}	2.12
T_9	1.25^{bcd}	2.45^{de}	3.47^{d}	4.73^{de}	2.98
T_{10}	1.08^{cde}	2.00^{efg}	3.08^{e}	3.99^{f}	2.54
T_{11}	0.96^{de}	1.51^{gh}	2.41^{f}	3.39^{g}	2.07
T_{12}	1.64^{b}	3.62^{b}	5.15^{b}	7.03^{b}	4.36
Mean	**1.33**	**2.60**	**3.85**	**5.21**	**3.25**
S. Em±	0.14	0.19	0.12	0.17	0.15
CD@5%	**0.44**	**0.57**	**0.38**	**0.53**	**0.63**

Note: Values with the same superscripts in same column are not significantly different by Duncan Multiple Range Test at $p \leq 0.05$.

T_1 – Control	T_7 – Pre-harvest spray of CCC 2500 ppm at 90 DAT
T_2 – Pre-harvest spray of SA (2 mM) at 60 + 90 DAT	T_8 – Pre-harvest spray of SA (2 mM) at 60+90 DAT + CCC 2500 ppm at 90 DAT
T_3 – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) at 60 + 90 DAT	T_9 – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) at 60 + 90 DAT+CCC 2500 ppm at 90 DAT
T_4 – Pre-harvest spray of azoxystrobin (0.1%) at 60 + 90 DAT	T_{10} – Pre-harvest spray of azoxystrobin (0.1%) + CCC 2500 ppm at 90 DAT
T_5 – Pre-harvest spray of SA (2 mM) + zoxystrobin (0.1%) at 60+90 DAT	T_{11} – Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT + CCC 2500 ppm at 90 DAT
T_6 – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT	T_{12} – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT + CCC 2500 ppm at 90 DAT

showed significant difference with T_{11} (2.41%) and T_8 (2.51%). In contrast, the treatment T_1 (Control) continued to have more rotting (8.30%) and it was significantly higher than rest of the treatments. This was closely followed by treatment T_{12} (5.15%).

At the end of 120 days of storage, lower rotting was continued to be seen in treatment T_5 (Pre-harvest spray of SA @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT) (3.05%), which was statistically on par with treatments T_{11} (3.39%) and T_8 (3.40%). Significantly higher rotting was noticed in treatments T_1 (Control) (12.69%) and it was followed by T_{12} (7.03%).

4.6 Black mould incidence (%)

It is visible from the results given in Table-6 that the per cent loss of bulbs due to black mould (*Aspergillus niger*) incidence increased with advancement in storage period. The treatments showed significant differences among themselves.

At 30 DAS, least incidence of black mould was observed in treatment T_{12} (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) (0.50%) which was found on par with the treatments T_6 (0.52%), T_{11} (0.55%), T_5 (0.57%), T_{10} (0.65%), T_8 (0.73%) and T_4 (0.83%). On contrary, the treatment T_1 (Control) (1.25%) exhibited maximum incidence of black mould. But it was found statistically on par with T_2 (0.89%), T_3 (0.92%) and T_7 (0.94%).

At 60 DAS the treatment T_{12} (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) (1.07%) exhibited least incidence of black mould followed by T_{11} (1.27%). On the other hand, the treatment T_1 (control) (3.87%) possessed significantly higher incidence of the disease than all other treatments.

After 90 DAS, the treatment T_{12} (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) (2.00%) recorded minimum

Table 6: Effect of field application of salicylic acid, azoxystrobin and cycocel on black mould (%) of onion bulbs (cv.Arka Kalyan) stored under ambient condition

Treatments	Black mould (%)				Mean
	Storage (Days)				
	30	60	90	120	
T_1	1.25^{a}	3.87^{a}	4.93^{a}	6.67^{a}	4.18
T_2	0.89^{abc}	2.82^{c}	3.70^{cd}	4.73^{d}	3.03
T_3	0.92^{abc}	1.78^{e}	3.87^{cd}	4.93^{cd}	2.87
T_4	0.83^{bcd}	1.40^{fg}	2.47^{ef}	3.52^{e}	2.05
T_5	0.57^{bcd}	1.83^{e}	2.73^{e}	3.50^{e}	2.16
T_6	0.52^{d}	2.15^{d}	3.47^{d}	4.80^{cd}	2.73
T_7	0.94^{ab}	3.27^{b}	4.53^{ab}	5.57^{b}	3.58
T_8	0.73^{bcd}	3.12^{bc}	4.60^{ab}	5.33^{bc}	3.45
T_9	0.72^{bcd}	3.00^{bc}	4.13^{bc}	5.10^{bcd}	3.24
T_{10}	0.65^{bcd}	1.71^{ef}	2.43^{ef}	3.27^{ef}	2.01
T_{11}	0.55^{cd}	1.27^{h}	2.17^{f}	3.17^{ef}	1.74
T_{12}	0.50^{d}	1.07^{gh}	2.00^{f}	2.77^{f}	1.63
Mean	**0.75**	**2.27**	**3.42**	**4.45**	**2.72**
S. Em±	0.12	0.10	0.18	0.19	0.15
CD@5%	**0.37**	**0.31**	**0.53**	**0.56**	**0.44**

Note: Values with the same superscripts in same column are not significantly different by Duncan Multiple Range Test at $p \leq 0.05$.

T_1 – Control	T_7 – Pre-harvest spray of CCC 2500 ppm at 90 DAT
T_2 – Pre-harvest spray of SA (2 mM) at 60 + 90 DAT	T_8 – Pre-harvest spray of SA (2 mM) at 60+90 DAT + CCC 2500 ppm at 90 DAT
T_3 – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) at 60 + 90 DAT	T_9 – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) at 60 + 90 DAT+CCC 2500 ppm at 90 DAT
T_4 – Pre-harvest spray of azoxystrobin (0.1%) at 60 + 90 DAT	T_{10} – Pre-harvest spray of azoxystrobin (0.1%) + CCC 2500 ppm at 90 DAT
T_5 – Pre-harvest spray of SA (2 mM) + zoxystrobin (0.1%) at 60+90 DAT	T_{11} – Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT + CCC 2500 ppm at 90 DAT
T_6 – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT	T_{12} – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT + CCC 2500 ppm at 90 DAT

incidence of black mould and it was on par with the treatments T_{11} (2.17%) and T_{10} (2.43%). However, T_1 (Control) (4.93%) continued to express maximum incidence of the same. But it showed non-significant differences with T_7 (4.53%) and T_8 (4.60%).

At the end of 120 days of storage, the treatment T_{12} (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) (2.77%) showed its effectiveness with minimum incidence of the disease and it was on par with treatment T_{11} (3.17%), and T_{10} (3.27%). However, the treatment T_1 (Control) possessed significantly maximum disease incidence of 6.67 per cent.

4.7 Marketable bulbs (%)

The mean per cent marketable bulbs decreased in all the treatments and it is evidenced from the mean values (92.42 per cent at 30 DAS to 69.51 per cent at 120 DAS). The pre-harvest treatments recorded significant differences with respect to percentage of marketable bulbs throughout the storage period (Table-7).

After 30 DAS, the treatment T_5 (Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) recorded maximum marketable bulbs of 94.49 per cent and it was found to be statistically on par with the treatment T_{11} (94.32%). However, the treatment T_1 (Control) resulted in significantly minimum (90.00%) over all other treatments.

At 60 DAS, the treatment T_{11} (Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) (85.73%) exhibited maximum per cent marketable bulbs followed by T_9 (84.90%), T_8 (84.75%) and T_6 (84.67%). On the other hand, the treatment T_1 (control) showed least per cent of marketable bulbs (74.27%).

After 90 DAS, treatment T_{11} (Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) (84.41%) recorded significantly maximum per cent of marketable bulbs. The treatment T_1 (Control) (63.65%) resulted in minimum per cent marketable bulbs and it differed significantly over all other treatments.

Table 7: Effect of field application of salicylic acid, azoxystrobin and cycocel on marketable bulb (%) of onion bulbs (cv. Arka Kalyan) stored under ambient condition

Treatments	Marketable bulb (%)				Mean
	Storage (Days)				
	30	60	90	120	
T_1	90.00^{h}	74.27^{e}	63.65^{i}	53.51^{h}	70.36
T_2	92.34^{cde}	81.95^{cd}	73.59^{h}	70.55^{e}	79.61
T_3	92.13^{de}	82.62^{cd}	74.85^{g}	70.79^{e}	80.10
T_4	92.38^{cde}	82.60^{cd}	76.46^{f}	70.54^{e}	80.39
T_5	94.49^{a}	83.64^{bc}	81.58^{bc}	74.36^{b}	83.52
T_6	93.19^{bc}	84.67^{ab}	79.46^{d}	72.12^{cd}	82.36
T_7	91.19^{fg}	81.33^{d}	77.93^{e}	65.40^{g}	78.96
T_8	92.00	84.75^{ab}	79.51^{d}	67.69^{f}	80.97
T_9	93.26^{b}	84.90^{ab}	82.54^{b}	70.93^{de}	82.91
T_{10}	90.72	81.54^{d}	78.07^{e}	68.57^{f}	79.73
T_{11}	94.32^{a}	85.73^{a}	84.41^{a}	77.04^{a}	85.54
T_{12}	93.00^{bcd}	83.14^{bcd}	80.54^{cd}	72.61^{c}	82.32
Mean	**92.42**	**82.59**	**77.72**	**69.51**	**80.56**
S. Em±	0.30	0.65	0.38	0.41	0.44
CD@5%	**0.88**	**1.92**	**1.14**	**1.21**	**1.29**

Note: Values with the same superscripts in same column are not significantly different by Duncan Multiple Range Test at $p \leq 0.05$.

T_1 – Control	T_7 – Pre-harvest spray of CCC 2500 ppm at 90 DAT
T_2 – Pre-harvest spray of SA (2 mM) at 60 + 90 DAT	T_8 – Pre-harvest spray of SA (2 mM) at 60+90 DAT + CCC 2500 ppm at 90 DAT
T_3 – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) at 60 + 90 DAT	T_9 – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) at 60 + 90 DAT+CCC 2500 ppm at 90 DAT
T_4 – Pre-harvest spray of azoxystrobin (0.1%) at 60 + 90 DAT	T_{10} – Pre-harvest spray of azoxystrobin (0.1%) + CCC 2500 ppm at 90 DAT
T_5 – Pre-harvest spray of SA (2 mM) + zoxystrobin (0.1%) at 60+90 DAT	T_{11} – Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT + CCC 2500 ppm at 90 DAT
T_6 – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT	T_{12} – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT + CCC 2500 ppm at 90 DAT

At 120 days after storage, the treatment T_{11} (Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) maintained significantly maximum (77.04%) marketable bulbs, whereas the least per cent marketable bulbs of 53.51 per cent was noticed in T_1 (Control).

4.8 Moisture content (%)

The data depicted in the Table 8 revealed decrease in moisture content of onion bulbs with advancement in the storage period. The mean moisture content, irrespective of treatments, decreased gradually from 84.71 per cent at initially to 80.35 per cent at 120 DAS.

Initially and at 30 DAS, non-significant differences were observed among the treatments. However, minimum moisture content was noticed in treatment T_4 (Pre-harvest spray of azoxystrobin @ 0.1% at 60 + 90 DAT) both in the beginning (84.16%) and at 30 DAS (82.83%). Maximum moisture content was exhibited by treatment T_1 (Control) (85.70%) initially and by the treatment T_{12} (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) (84.01%) at 30 DAS.

With progress in storage up to 60 days, the treatment T_4 (Pre-harvest spray of azoxystrobin @ 0.1% at 60 + 90 DAT) showed significantly minimum moisture (81.52%). The treatment T_{12} (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) continued to have maximum moisture content (82.99%).

At 90 days, the treatment T_4 (Pre-harvest spray of azoxystrobin @ 0.1% at 60 + 90 DAT) (80.65%) showed significantly least moisture content. On contrary, the treatment T_6 (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid @ 2 mM followed by foliar spray of azoxystrobin @ 0.1% at 60 + 90 DAT) exhibited maximum moisture (81.91%) and it was on par with treatments T_8 (81.67%), T_9 (81.65%), T_2 (81.63%), T_3 (81.84%), T_{11} (81.72%) and T_{12} (81.63%).

Table 8: Effect of field application of salicylic acid, azoxystrobin and cycocel on moisture content (%) of onion cv. Arka Kalyan stored under ambient condition

Treatments	Moisture content (%)					Mean
	Storage (Days)					
	Initial	30	60	90	120	
T_1	85.70	83.94	82.47^{bc}	81.31^{d}	80.28^{c}	82.74
T_2	84.44	82.85	82.07^{c}	81.63^{abc}	80.65^{abc}	82.33
T_3	84.55	83.74	82.82^{ab}	81.84^{ab}	80.81^{ab}	82.75
T_4	84.16	82.83	81.52^{d}	80.65^{e}	78.85^{d}	81.60
T_5	84.43	83.72	82.77^{ab}	81.68^{abc}	80.28^{c}	82.58
T_6	84.27	83.60	82.72^{ab}	81.91^{a}	80.85^{a}	82.67
T_7	85.15	83.21	82.69^{ab}	81.4^{cd}	80.26^{c}	82.56
T_8	84.62	83.52	82.38^{bc}	81.67^{abc}	80.46^{abc}	82.53
T_9	84.23	83.33	82.43^{bc}	81.65^{abc}	80.40^{abc}	82.41
T_{10}	84.99	83.15	82.06^{c}	81.54^{bcd}	80.37^{bc}	82.42
T_{11}	84.47	83.45	82.75^{ab}	81.72^{abc}	80.69^{abc}	82.61
T_{12}	85.48	84.01	82.99^{a}	81.63^{abc}	80.29^{c}	82.88
Mean	**84.71**	**83.45**	**82.47**	**81.56**	**80.35**	**82.51**
S. Em±	0.53	0.35	0.15	0.10	0.15	0.26
CD@5%	**NS**	**NS**	**0.45**	**0.31**	**0.47**	**0.25**

Note: Values with the same superscripts in same column are not significantly different by Duncan Multiple Range Test at $p \leq 0.05$.

T_1 – Control	T_7 – Pre-harvest spray of CCC 2500 ppm at 90 DAT
T_2 – Pre-harvest spray of SA (2 mM) at 60 + 90 DAT	T_8 – Pre-harvest spray of SA (2 mM) at 60+90 DAT + CCC 2500 ppm at 90 DAT
T_3 – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) at 60 + 90 DAT	T_9 – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) at 60 + 90 DAT+CCC 2500 ppm at 90 DAT
T_4 – Pre-harvest spray of azoxystrobin (0.1%) at 60 + 90 DAT	T_{10} – Pre-harvest spray of azoxystrobin (0.1%) + CCC 2500 ppm at 90 DAT
T_5 – Pre-harvest spray of SA (2 mM) + zoxystrobin (0.1%) at 60+90 DAT	T_{11} – Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT + CCC 2500 ppm at 90 DAT
T_6 – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT	T_{12} – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT + CCC 2500 ppm at 90 DAT

At the end of 120 days of storage study, least moisture content was noticed in treatment T_4 (Pre harvest spray of azoxystrobin @ 0.1% at 60 + 90 DAT) (78.85%). However, maximum moisture observed in treatment T_6 (Seedling dip in salicylic acid @ 2mM + Pre-harvest spray of salicylic acid @ 2 mM followed by foliar spray of azoxystrobin @ 0.1% at 60 + 90 DAT) (80.85%) did not differ significantly with T_2 (80.65%), T_3 (80.81%), T_8 (80.46%), T_9 (80.40%) and T_{11} (80.69%).

4.9 Dry matter content (%)

In general, dry matter content of onion bulbs increased as the storage duration progressed in all the treatments (Table 9). At the beginning of storage, higher dry matter was observed in treatment T_4 (Pre-harvest spray of azoxystrobin @ 0.1% at 60 + 90 DAT) (15.83%) and the treatment T4 was found to be non-significantly differing with by T_9 (15.66%), T_6 (15.61%), T_2 (15.55%) and T_5 (15.51%). The least dry matter content was observed in the treatment T_1 (Control) (14.30%).

After 30, 60, 90 and 120 days of storage, maximum dry matter content was recorded in the treatment T_4 (Pre-harvest spray of azoxystrobin @ 0.1% at 60 + 90 DAT) (17.09%, 18.45%, 19.35% and 21.16% respectively). The treatment T_4 was on par with treatments T_9 (16.70%), T_7 (16.69%), T_2 (16.63%), T_{10} (16.55%), T_{11} (16.54%), T_8 (16.49%), T_6 (16.47%) at the end of 30 days. However, there were no significant differences among the treatments at 60 days of storage.

The treatment T_1 (Control) (15.52%) followed by treatment T_{12} (15.74%) showed minimum dry matter content at 30 days. After 60 DAS, treatment T_{12} (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) (16.82%) followed by T_1 (Control) (16.86%) exhibited least dry matter content. Minimum dry matter content was noticed in T_6 (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid @ 2 mM followed by foliar spray of azoxystrobin @ 0.1% at 60 + 90 DAT) (18.13%) after 90 days of storage. The least

Table 9: Effect of field application of salicylic acid, azoxystrobin and cycocel on dry matter (%) of onion bulbs (cv.Arka Kalyan) stored under ambient condition

Treatments	Dry matter (%)					Mean
	Storage (Days)					
	Initial	30	60	90	120	
T_1	14.30^{d}	15.52^{d}	16.86	18.61^{bc}	19.72^{bc}	17.00
T_2	15.55^{a}	16.63^{ab}	17.61	18.37^{d}	19.31^{d}	17.49
T_3	15.40^{ab}	16.35^{bc}	17.07	18.16^{e}	19.20^{d}	17.24
T_4	15.83^{a}	17.09^{a}	18.45	19.35^{a}	21.16^{a}	18.38
T_5	15.51^{ab}	16.29^{bc}	17.23	18.41^{d}	19.69^{bc}	17.52
T_6	15.61^{a}	16.47^{ab}	17.51	18.13^{e}	19.15^{d}	17.37
T_7	14.77^{cd}	16.69^{ab}	17.32	18.60^{bc}	19.74^{b}	17.42
T_8	15.34^{ab}	16.49^{ab}	17.61	18.42^{d}	19.54^{c}	17.48
T_9	15.66^{a}	16.70^{ab}	17.60	18.65^{bc}	19.60^{bc}	17.59
T_{10}	15.01^{ab}	16.55^{ab}	17.94	18.46^{de}	19.61^{bc}	17.47
T_{11}	15.53^{a}	16.54^{ab}	17.25	18.28^{d}	19.29^{d}	17.38
T_{12}	14.53^{cd}	15.74^{cd}	16.82	18.37^{b}	19.63^{bc}	17.02
Mean	**15.25**	**16.42**	**17.44**	**18.48**	**19.64**	**17.45**
S. Em±	0.17	0.24	0.64	0.07	0.06	0.23
CD@5%	**0.50**	**0.72**	**NS**	**0.18**	**0.18**	**0.32**

Note: Values with the same superscripts in same column are not significantly different by Duncan Multiple Range Test at $p \leq 0.05$

T_1 – Control	T_7 – Pre-harvest spray of CCC 2500 ppm at 90 DAT
T_2 – Pre-harvest spray of SA (2 mM) at 60 + 90 DAT	T_8 – Pre-harvest spray of SA (2 mM) at 60+90 DAT + CCC 2500 ppm at 90 DAT
T_3 – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) at 60 + 90 DAT	T_9 – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) at 60 + 90 DAT+CCC 2500 ppm at 90 DAT
T_4 – Pre-harvest spray of azoxystrobin (0.1%) at 60 + 90 DAT	T_{10} – Pre-harvest spray of azoxystrobin (0.1%) + CCC 2500 ppm at 90 DAT
T_5 – Pre-harvest spray of SA (2 mM) + zoxystrobin (0.1%) at 60+90 DAT	T_{11} – Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT + CCC 2500 ppm at 90 DAT
T_6 – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT	T_{12} – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT + CCC 2500 ppm at 90 DAT

dry matter at the end of 120 days of storage was recorded by the treatment T_6 (19.15%) which is on par with the treatments T_2 (19.31%), T_3 (19.20%), and T_{11} (19.29 %).

4.10 Bulb firmness (N)

In general, firmness of onion bulbs was found to decrease as the storage duration progressed in all the treatments (Table 10).

Initially the treatments did not show significant differences for firmness. Nevertheless, the maximum firmness was recorded in the treatment T_{11} (Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) (128.08 N) and the lower firmness was recorded in treatment T_4 (Pre-harvest spray of azoxystrobin @ 0.1% at 60 + 90 DAT) (123.89 N) and T_7 (Pre-harvest spray of CCC 2500 ppm at 90 DAT) (124.39 N).

Even after 30 days of storage, onions of the treatment T_{11} (Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) (126.31 N) were found to be more firmer. But they were on par with that of T_{12} (125.41 N), T_9 (125.00 N), T_3 (124.15 N), T_2 (123.44 N), T_6 (124.05 N) and T_8 (122.92 N). On contrary, minimum firmness elucidated by treatment T_1 (Control) (120.09 N).

Significantly maximum firmness at 60 days after storage was recorded in treatment T_{11} (Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) (124.17 N) which was on par with T_{12} (123.85 N). More loss of firmness was noticed in treatment T_1 (Control) (117.09 N) followed by T_4 (118.79 N) and T_7 (119.45N)

With further progress in storage for 90 days, the treatment T_{11} (Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) (121.83 N) recorded maximum firmness followed by treatment T_9 (120.67 N), T_{12} (120.13 N) and T_6 (119.92 N). Onions of the treatment T_1 (Control) were found to have significantly lower firmness (114.26N).

Table 10: Effect of field application of salicylic acid, azoxystrobin and cycocel on firmness (N) of onion bulbs (cv.Arka Kalyan) stored under ambient condition

Treatments		Bulb firmness(N)				Mean
		Storage (Days)				
	Initial	30	60	90	120	
T_1	125.21	120.09^{c}	117.09^{i}	114.26^{g}	110.62^{c}	117.45
T_2	126.66	123.44^{abc}	121.74^{de}	119.27^{bcde}	116.74^{ab}	121.57
T_3	126.66	124.15^{ab}	121.38^{de}	118.41^{cdef}	115.84^{ab}	121.29
T_4	123.89	120.37^{c}	118.79^{h}	117.19^{f}	113.95^{bc}	118.84
T_5	125.92	122.54^{bc}	120.90^{ef}	119.00^{bcdef}	117.08^{ab}	121.09
T_6	126.16	124.05^{ab}	122.34^{cd}	119.92^{abcd}	116.72^{ab}	121.84
T_7	124.39	122.37^{bc}	119.45^{gh}	117.36^{ef}	115.63^{ab}	119.84
T_8	124.68	122.92^{abc}	121.23^{ef}	117.85^{def}	113.43^{bc}	120.02
T_9	127.94	125.00^{ab}	123.10^{bc}	120.67^{ab}	117.31^{ab}	122.80
T_{10}	128.05	122.55^{bc}	120.22^{fg}	118.45^{cdef}	115.51^{ab}	120.96
T_{11}	128.08	126.31^{a}	124.17^{a}	121.83^{a}	119.52^{a}	123.98
T_{12}	127.53	125.41^{ab}	123.85^{ab}	120.13^{abc}	116.68^{ab}	122.72
Mean	**126.26**	**123.27**	**121.19**	**118.69**	**115.75**	**121.03**
S. Em±	1.76	1.21	0.34	0.70	1.47	1.10
CD@5%	**NS**	**3.58**	**1.03**	**2.07**	**4.34**	**2.20**

Note: Values with the same superscripts in same column are not significantly different by Duncan Multiple Range Test at $p \leq 0.05$.

T_1 – Control	T_7 – Pre-harvest spray of CCC 2500 ppm at 90 DAT
T_2 – Pre-harvest spray of SA (2 mM) at 60 + 90 DAT	T_8 – Pre-harvest spray of SA (2 mM) at 60+90 DAT + CCC 2500 ppm at 90 DAT
T_3 – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) at 60 + 90 DAT	T_9 – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) at 60 + 90 DAT+CCC 2500 ppm at 90 DAT
T_4 – Pre-harvest spray of azoxystrobin (0.1%) at 60 + 90 DAT	T_{10} – Pre-harvest spray of azoxystrobin (0.1%) + CCC 2500 ppm at 90 DAT
T_5 – Pre-harvest spray of SA (2 mM) + zoxystrobin (0.1%) at 60+90 DAT	T_{11} – Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT + CCC 2500 ppm at 90 DAT
T_6 – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT	T_{12} – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT + CCC 2500 ppm at 90 DAT

At the end of 120 days of storage, higher firmness was noticed with the treatment T_{11} (Pre-harvest spray of salicylic acid-2mM at 60 + 90 DAT) (119.52 N). This treatment T_{11} was on par with the treatments T_9 (117.31N), T_5 (117.08 N), T_2 (116.74 N), T_6 (116.72 N), T_{12} (116.68 N), T_3 (115.84 N), T_7 (115.63 N) and T_{10} (115.51 N). Significantly minimum firmness recorded consecutively by control onions (T_1) (110.62 N) was, however, statistically on par with T_4 (113.95 N) and T_8 (113.43 N).

4.11 Total soluble solids (°B)

The data depicting the influence of field application of salicylic acid, azoxystrobin and cycocel on TSS of onion cv. Arka Kalyan during storage under ambient condition are given in Table 11. In general, the TSS content increased initially during storage and then declined with progress of senescence.

Fresh onion bulbs after harvest and before storage revealed a non-significant difference among the treatments for TSS. However, maximum TSS was noticed in treatment T_5 (Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT) (13.8^{o}B) followed by T_{10} (13.73^{o}B), T_4 (13.70^{o}B) and T_{12} (13.70 ^{o}B). On contrary, the least TSS was recorded by the treatment T_1 (Control) (13.07 ^{o}B) followed by T_6 (13.10^{o}B)

After 30 days of storage, highest TSS was noticed in the treatment T_{11} (Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) (14.73^{o}B) and it did not differ significantly with T_5 (14.30 ^{o}B), T_{10} (14.47 ^{o}B) and T_{12} (14.43 ^{o}B). The least TSS recorded in the treatment T_1 (Control) (13.63^{o}B) was on par with T_2 (13.76^{o}B), T_3 (13.82 ^{o}B), T_6 (13.80^{o}B), T_8 (13.90^{o}B) and T_9 (13.80^{o}B).

At 60 DAS also, maximum TSS was noticed in the treatment T_{11} (Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) (15.24 ^{o}B) and it was on par with T_{10} (14.89 ^{o}B) and T_{12} (14.82^{o}B). The treatment T_2 continued to show the least TSS (14.06^{o}B) and remained stastically similar to T_1 (14.17 ^{o}B), T_3 (14.30 ^{o}B), and T_6 (14.52 ^{o}B).

Table 11: Effect of field application of salicylic acid, azoxystrobin and cycocel on total soluble solids (TSS^{o}B) of onion bulbs (cv. Arka Kalyan) stored under ambient condition

Treatments	TSS (^{o}B)					Mean
	Storage (Days)					
	Initial	30	60	90	120	
T_1	13.07	13.63^{e}	14.17^{ef}	14.86^{ef}	14.31^{d}	14.23
T_2	13.47	13.76^{e}	14.06^{f}	14.60^{f}	14.30^{d}	14.22
T_3	13.37	13.82^{de}	14.30^{def}	14.83^{ef}	14.37^{cd}	14.26
T_4	13.70	14.23^{bcd}	15.00^{ab}	15.53^{ab}	14.70^{ab}	14.88
T_5	13.80	14.30^{abc}	14.73^{bcd}	15.18^{bcde}	14.62^{abc}	14.75
T_6	13.10	13.80^{de}	14.52^{cdef}	15.07^{cde}	14.58^{bcd}	14.43
T_7	13.43	14.20^{bcd}	14.83^{abc}	15.56^{ab}	14.64^{abc}	14.83
T_8	13.63	13.90^{cde}	14.53^{cde}	15.03^{def}	14.53^{bcd}	14.54
T_9	13.50	13.80^{de}	13.33^{g}	14.08^{g}	13.93^{e}	13.93
T_{10}	13.73	14.47^{ab}	14.89^{abc}	15.49^{abc}	14.69^{ab}	14.91
T_{11}	13.67	14.73^{a}	15.24^{a}	15.76^{a}	14.89^{a}	15.14
T_{12}	13.70	14.43^{ab}	14.82^{abc}	15.45^{abcd}	14.74^{ab}	14.93
Mean	**13.51**	**14.09**	**14.54**	**15.12**	**14.52**	**14.37**
S. Em±	0.15	0.14	0.15	0.15	0.09	0.14
CD@5%	**NS**	**0.44**	**0.47**	**0.45**	**0.30**	**0.41**

Note: Values with the same superscripts in same column are not significantly different by Duncan Multiple Range Test at $p \leq 0.05$.

T_1 – Control	T_7 – Pre-harvest spray of CCC 2500 ppm at 90 DAT
T_2 – Pre-harvest spray of SA (2 mM) at 60 + 90 DAT	T_8 – Pre-harvest spray of SA (2 mM) at 60+90 DAT + CCC 2500 ppm at 90 DAT
T_3 – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) at 60 + 90 DAT	T_9 – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) at 60 + 90 DAT+CCC 2500 ppm at 90 DAT
T_4 – Pre-harvest spray of azoxystrobin (0.1%) at 60 + 90 DAT	T_{10} – Pre-harvest spray of azoxystrobin (0.1%) + CCC 2500 ppm at 90 DAT
T_5 – Pre-harvest spray of SA (2 mM) + zoxystrobin (0.1%) at 60+90 DAT	T_{11} – Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT + CCC 2500 ppm at 90 DAT
T_6 – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT	T_{12} – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT + CCC 2500 ppm at 90 DAT

With advancement in storage up to 90 days, highest TSS was recorded in treatment T_{11} (Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) (15.76^{o}B) and it was statistically similar to treatment T_{12} (15.45 ^{o}B), T_{10} (15.49 ^{o}B), T_{7} (15.56 ^{o}B) and T_{4} (15.53 ^{o}B). Minimum TSS was observed in the treatment T_{9} (14.08^{o}B).

At the end of 120 days of storage, a slight decrease in TSS was noticed. The treatment T_{11} (Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) retained maximum TSS (14.89^{o}B). However, the least TSS was recorded in T_{1} (Control) (14.31^{o}B).

4.12 Total phenol content (mg/100 g)

The observations on total phenol content of onion bulbs as influenced by different pre harvest sprays during storage under ambient condition are presented in Table 12. The data revealed the presence of significant differences among the treatments with respect to total phenol content. In general, the total phenol content decreased as the storage period progressed.

Initially, bulbs of the treatment T_{6} (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid @ 2 mM followed by foliar spray of azoxystrobin @ 0.1% at 60 + 90 DAT) recorded significantly maximum total phenol content (15.80 mg/100 g) which was on par with treatment T_{5} (15.60 mg/100 g). On the other hand, significantly minimum phenol content was observed in T_{1} (Control) (11.67 mg/100 g).

After 30 days of storage under ambient condition, the total phenol content was found maximum in the treatment T_{6} (14.33 mg/100 g) which was on par with the treatment T_{5} (14.10 mg/100 g). On the contrary, minimum total phenol noted in treatment T_{1} (Control) (10.80 mg/100 g).

At the end of 60 days of storage, the same treatment (T_{6}) (13.77 mg/100 g) showed significantly higher levels of phenols. However, minimum total phenol content was again associated with T_{1} (Control) (10.33 mg/100 g).

With further progress in storage (after 90 days), significantly maximum content of total phenol was found in the treatment T_{6} (12.90 mg/100 g), whereas

Table 12: Effect of on field application of salicylic acid, azoxystrobin and cycocel on total phenol (mg/100g) of onion bulbs (cv. Arka Kalyan) stored under ambient condition

Treatments	Total phenol (mg/100g)					Mean
	Storage (Days)					
	Initial	30	60	90	120	
T_1	11.67^{i}	10.80^{f}	10.33^{g}	9.37^{f}	8.27^{e}	10.09
T_2	13.20^{ef}	12.67^{bc}	11.60^{ef}	10.63^{de}	9.70^{cd}	11.56
T_3	13.47^{cde}	12.83^{bc}	11.82^{cde}	10.80^{d}	9.83^{c}	11.75
T_4	13.55^{cd}	12.90^{bc}	11.53^{f}	10.77^{d}	9.77^{c}	11.70
T_5	15.60^{a}	14.10^{a}	13.70^{a}	12.67^{a}	11.63^{a}	13.54
T_6	15.80^{a}	14.33^{a}	13.77^{a}	12.90^{a}	11.83^{a}	13.73
T_7	12.37^{h}	11.53^{e}	10.47^{g}	9.30^{f}	7.87^{f}	10.31
T_8	13.13^{f}	12.10^{d}	11.60^{ef}	10.40^{e}	9.43^{d}	11.33
T_9	12.80^{g}	12.57^{c}	11.70^{def}	10.77^{e}	9.73^{cd}	11.51
T_{10}	13.38^{def}	12.80^{bc}	12.00^{c}	11.13^{c}	10.27^{b}	11.92
T_{11}	13.73^{c}	13.00^{b}	12.80^{b}	11.57^{b}	10.57^{b}	12.33
T_{12}	14.18^{b}	12.83^{bc}	11.90^{cd}	11.37^{bc}	10.33^{b}	12.12
Mean	**13.57**	**12.71**	**11.93**	**10.97**	**9.94**	**11.82**
S. Em±	0.10	0.12	0.05	0.10	0.11	0.10
CD@5%	**0.31**	**0.38**	**0.24**	**0.29**	**0.32**	**0.31**

Note: Values with the same superscripts in same column are not significantly different by Duncan Multiple Range Test at $p \leq 0.05$.

T_1 – Control	T_7 – Pre-harvest spray of CCC 2500 ppm at 90 DAT
T_2 – Pre-harvest spray of SA (2 mM) at 60 + 90 DAT	T_8 – Pre-harvest spray of SA (2 mM) at 60+90 DAT + CCC 2500 ppm at 90 DAT
T_3 – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) at 60 + 90 DAT	T_9 – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) at 60 + 90 DAT+CCC 2500 ppm at 90 DAT
T_4 – Pre-harvest spray of azoxystrobin (0.1%) at 60 + 90 DAT	T_{10} – Pre-harvest spray of azoxystrobin (0.1%) + CCC 2500 ppm at 90 DAT
T_5 – Pre-harvest spray of SA (2 mM) + zoxystrobin (0.1%) at 60+90 DAT	T_{11} – Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT + CCC 2500 ppm at 90 DAT
T_6 – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT	T_{12} – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT + CCC 2500 ppm at 90 DAT

minimum total phenols content was associated with the treatment T_1 (Control) (9.37 mg/100 g).

Even after the end of 120 DAS, the treatment T_6 was found to retain maximum phenolic content (11.83 mg/100 g). However treatment T_1 (Control) (8.27 mg/100 g) continued to show tendency retain lower phenol content.

4.13 Pyruvic acid (µmoles/g)

The pyruvic acid content of onion bulbs different storage revealed significant differences among the treatments (Table 13). In general, the pyruvic acid content showed a decreasing trend as the storage period progressed.

Initially, significantly higher content of pyruvic acid was recorded in the treatment T_6 (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT) (9.50 µmoles/gm) and it was on par with the treatment T_{12} (9.33 µmoles/gm). Minimum content of pyruvic acid was found in T_1 (Control) (5.27 µmoles/gm).

After 30 days of storage under ambient condition the pyruvic acid content was found to be maximum in the treatment T_6 (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT) (9.23 µmoles/gm) and it showed parity with the treatment T_{12} (9.00 µmoles/gm), T_5 (9.13 µmoles/gm) and T_3 (9.20 µmoles/gm). On contrary, treatment T_1 (control) continue the trend of showing minimum pungency (5.10 µmoles/gm).

At the end of 60 days of storage, significantly maximum pyruvic acid content was noticed in the treatment T_6 (8.80 µmoles/gm) and it was on par with the treatment T_{12} (8.57 µmoles/gm). Significantly minimum pyruvic acid content was found in the treatment T_1 (Control) (4.77 µmoles/gm) over all other treatments.

At 90 days of storage, pyruvic acid content was continued to be maximum in the treatment T_6 (8.23 µmoles/gm) and it showed parity with the treatment T_5 (8.10 µmoles/gm). In contrast, minimum content of pyruvic acid was continued to be present in the treatment T_1 (Control) (4.07 µmoles/gm).

Table 13: Effect of on field application of salicylic acid, azoxystrobin and cycocel on total pyruvic acid (µmoles/g) of onion bulbs (cv. Arka Kalyan) stored under ambient condition

Treatments	Pyruvic acid (µmoles/g)					Mean
	Storage (Days)					
	Initial	30	60	90	120	
T_1	5.27^{j}	5.10^{e}	4.77^{e}	4.07^{g}	3.43^{e}	4.53
T_2	9.03^{d}	8.47^{b}	7.97^{b}	7.40^{c}	6.60^{b}	7.81
T_3	9.13^{cd}	9.20^{a}	8.80^{a}	8.23^{a}	6.63^{b}	7.96
T_4	7.40^{h}	6.83^{d}	6.37^{d}	5.97^{e}	5.30^{d}	6.37
T_5	9.30^{bc}	9.13^{a}	8.67^{a}	8.10^{a}	7.67^{a}	8.57
T_6	9.50^{a}	9.23^{a}	8.80^{a}	8.23^{a}	7.90^{a}	8.71
T_7	7.63^{g}	6.90^{d}	6.33^{d}	5.63^{d}	5.17^{d}	6.33
T_8	8.50^{f}	8.03^{c}	7.43^{c}	6.97^{d}	6.17^{c}	7.42
T_9	8.73^{e}	8.07^{c}	7.70^{bc}	7.07^{d}	6.60^{b}	7.63
T_{10}	7.20^{i}	6.87^{d}	6.47^{d}	5.90^{ef}	5.27^{d}	6.34
T_{11}	9.00^{d}	8.67^{b}	7.90^{b}	7.10^{cd}	6.60^{b}	7.81
T_{12}	9.33^{ab}	9.00^{a}	8.57^{a}	7.73^{b}	6.73^{b}	8.31
Mean	**8.34**	**7.96**	**7.39**	**6.75**	**6.14**	**7.30**
S. Em±	0.06	0.07	0.10	0.10	0.09	0.08
CD@5%	**0.20**	**0.25**	**0.31**	**0.31**	**0.26**	**0.27**

Note: Values with the same superscripts in same column are not significantly different by Duncan Multiple Range Test at $p \leq 0.05$.

T_1 – Control	T_7 – Pre-harvest spray of CCC 2500 ppm at 90 DAT
T_2 – Pre-harvest spray of SA (2 mM) at 60 + 90 DAT	T_8 – Pre-harvest spray of SA (2 mM) at 60+90 DAT + CCC 2500 ppm at 90 DAT
T_3 – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) at 60 + 90 DAT	T_9 – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) at 60 + 90 DAT+CCC 2500 ppm at 90 DAT
T_4 – Pre-harvest spray of azoxystrobin (0.1%) at 60 + 90 DAT	T_{10} – Pre-harvest spray of azoxystrobin (0.1%) + CCC 2500 ppm at 90 DAT
T_5 – Pre-harvest spray of SA (2 mM) + zoxystrobin (0.1%) at 60+90 DAT	T_{11} – Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT + CCC 2500 ppm at 90 DAT
T_6 – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT	T_{12} – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT + CCC 2500 ppm at 90 DAT

Even after 120 DAS, the treatment T_6 continued to record maximum pyruvic acid content (7.90 µmoles/gm) which was on par with the treatment T_5 (7.67 µmoles/gm). However treatment T_1 (control) (3.43 µmoles/gm) remained to contain the minimum level of pyruvic acid.

4.14 Sensory evaluation

4.14.1 Colour (score out of 9)

The data regarding sensory evaluation of skin colour of onion bulbs (variety Arka Kalyan) as influenced during storage by field application of salicylic acid, azoxystrobin and cycocel are given in Table 14. The overall mean revealed significant differences among the treatments. However, numerically maximum mean score (8.08 out of 9) for bulb colour was seen in the treatment T_8 (Pre-harvest spray of salicylic acid @ 2 mM at 60 + 90 DAT and foliar spray of CCC 2500 ppm 90 DAT) followed by T_{10} (Pre-harvest spray of azoxystrobin-0.05% at 90 DAT) (7.95 out of 9). However, the treatment T_{12} (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) (7.62 out of 9) scored minimum in comparison with other treatments.

4.14.2 Texture

The influence of field application salicylic acid, azoxystrobin and cycocel on texture of bulbs was found to be significant (Table 15). Numerically maximum mean score for bulb texture was recorded in the treatment T_{11} (Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) (7.88 out of 9). However, minimum score was received by the treatment T_9 (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid @ 2 mM at 60 + 90 DAT and foliar spray CCC 2500 ppm 90 DAT) (7.54 out of 9).

4.14.3 Taste and flavor

The data regarding sensory evaluation of flavour and taste of onion bulbs (variety Arka Kalyan) as influenced by field application of salicylic acid, azoxystrobin

Table 14: Effect of field application of salicylic acid, azoxystrobin and cycocel on colour of onion bulbs (cv. Arka Kalyan) stored under ambient condition

Treatments	Colour					Mean
	Storage (Days)					
	Initial	30	60	90	120	
T_1	8.12^{cde}	7.92^{d}	7.80^{de}	7.57	7.13^{cde}	7.71
T_2	7.90^{fgh}	7.88^{d}	7.77^{e}	7.53	7.53^{a}	7.72
T_3	8.00^{def}	7.95^{d}	7.90^{cde}	7.73	7.37^{ab}	7.79
T_4	7.82^{fgh}	8.05^{c}	7.77^{e}	7.60	7.33^{abc}	7.71
T_5	7.95^{efg}	8.19^{b}	7.97^{bc}	7.80	7.40^{ab}	7.86
T_6	7.80^{gh}	8.05^{c}	7.93^{bcd}	7.56	7.23^{bcd}	7.72
T_7	8.28^{abc}	7.77^{e}	7.93^{bcd}	7.65	7.40^{ab}	7.81
T_8	8.40^{a}	8.37^{a}	8.33^{a}	7.79	7.50^{a}	8.08
T_9	7.73^{h}	7.89^{d}	7.90^{cde}	7.69	7.47^{a}	7.74
T_{10}	8.17^{bcd}	8.19^{b}	8.07^{b}	7.78	7.53^{a}	7.95
T_{11}	8.33^{ab}	8.09^{bc}	7.87^{cde}	7.47	7.10^{de}	7.77
T_{12}	7.77^{gh}	7.93^{d}	7.80^{de}	7.60	7.00^{e}	7.62
Mean	**8.02**	**8.02**	**7.92**	**7.65**	**7.33**	**7.79**
S. Em±	0.06	0.04	0.03	0.08	0.06	0.05
CD@5%	**0.18**	**0.10**	**0.16**	**NS**	**0.21**	**0.13**

Note: Values with the same superscripts in same column are not significantly different by Duncan Multiple Range Test at $p \leq 0.05$.

T_1 – Control	T_7 – Pre-harvest spray of CCC 2500 ppm at 90 DAT
T_2 – Pre-harvest spray of SA (2 mM) at 60 + 90 DAT	T_8 – Pre-harvest spray of SA (2 mM) at 60+90 DAT + CCC 2500 ppm at 90 DAT
T_3 – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) at 60 + 90 DAT	T_9 – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) at 60 + 90 DAT+CCC 2500 ppm at 90 DAT
T_4 – Pre-harvest spray of azoxystrobin (0.1%) at 60 + 90 DAT	T_{10} – Pre-harvest spray of azoxystrobin (0.1%) + CCC 2500 ppm at 90 DAT
T_5 – Pre-harvest spray of SA (2 mM) + zoxystrobin (0.1%) at 60+90 DAT	T_{11} – Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT + CCC 2500 ppm at 90 DAT
T_6 – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT	T_{12} – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT + CCC 2500 ppm at 90 DAT

and cycocel during storage period of 120 days was found to be non-significant (Table 16). Nevertheless, numerically maximum mean score for bulb flavour and taste was observed in the treatment T_8 (Pre-harvest spray of salicylic acid @ 2 mM at 60 + 90 DAT and foliar spray of CCC 2500 ppm 90 DAT) (7.83 out of 9) and minimum score by the treatment T_2 (Pre-harvest spray of salicylic acid @ 2 mM at 60 + 90 DAT) (7.2 out of 9).

4.14.4 Overall acceptability

The data regarding sensory evaluation of overall acceptability of onion bulbs (variety Arka Kalyan) as influenced by field application of salicylic acid, azoxystrobin and cycocel with prolong storage of 120 days was presented in the Table-17. The treatment T_8 (Pre-harvest spray of salicylic acid @ 2 mM at 60 + 90 DAT and foliar spray of CCC 2500 ppm 90 DAT) (7.9 out of 9) exhibited numerically maximum mean score for overall acceptability and minimum score was noticed in treatment T_9 (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid @ 2 mM at 60 + 90 DAT and foliar spray CCC 2500 ppm 90 DAT) (7.57 out of 9).

Table 15: Effect of field application of salicylic acid, azoxystrobin and cycocel on texture of onion bulbs (cv. Arka Kalyan) stored under ambient condition

Treatments	Texture					Mean
	Storage (Days)					
	Initial	30	60	90	120	
T_1	7.93^{c}	7.78^{cd}	7.60	7.53^{bc}	7.13^{d}	7.60
T_2	7.78^{c}	7.82^{bcd}	7.73	7.58^{ab}	7.43^{abc}	7.67
T_3	7.88^{c}	7.83^{bc}	7.60	7.63^{ab}	7.47^{ab}	7.68
T_4	7.78^{c}	7.70^{cd}	7.67	7.53^{bc}	7.23^{bcd}	7.58
T_5	8.03^{bc}	7.82^{bcd}	7.70	7.63^{ab}	7.33^{abcd}	7.70
T_6	7.95^{c}	7.80^{cd}	7.63	7.50^{bc}	7.23^{bcd}	7.62
T_7	7.97^{c}	7.67^{d}	7.47	7.37^{c}	7.40^{abcd}	7.57
T_8	8.33^{a}	8.02^{a}	7.70	7.55^{bc}	7.43^{abc}	7.81
T_9	7.93^{c}	7.67^{d}	7.57	7.37^{c}	7.17^{cd}	7.54
T_{10}	7.93^{c}	7.85^{bc}	7.67	7.58^{ab}	7.13^{d}	7.63
T_{11}	8.27^{ab}	7.97^{ab}	7.80	7.75^{a}	7.60^{a}	7.88
T_{12}	7.78^{c}	7.67^{d}	7.60	7.58^{ab}	7.20^{bcd}	7.57
Mean	**7.96**	**7.80**	**7.64**	**7.55**	**7.31**	**7.65**
S. Em±	0.08	0.04	0.57	0.07	0.09	0.17
CD@5%	**0.27**	**0.16**	**NS**	**0.20**	**0.28**	**0.18**

Note: Values with the same superscripts in same column are not significantly different by Duncan Multiple Range Test at $p \leq 0.05$.

T_1 – Control	T_7 – Pre-harvest spray of CCC 2500 ppm at 90 DAT
T_2 – Pre-harvest spray of SA (2 mM) at 60 + 90 DAT	T_8 – Pre-harvest spray of SA (2 mM) at 60+90 DAT + CCC 2500 ppm at 90 DAT
T_3 – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) at 60 + 90 DAT	T_9 – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) at 60 + 90 DAT+CCC 2500 ppm at 90 DAT
T_4 – Pre-harvest spray of azoxystrobin (0.1%) at 60 + 90 DAT	T_{10} – Pre-harvest spray of azoxystrobin (0.1%) + CCC 2500 ppm at 90 DAT
T_5 – Pre-harvest spray of SA (2 mM) + zoxystrobin (0.1%) at 60+90 DAT	T_{11} – Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT + CCC 2500 ppm at 90 DAT
T_6 – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT	T_{12} – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT + CCC 2500 ppm at 90 DAT

Table 16: Effect of seedling dip and pre-harvest sprays on flavour and taste of onion bulbs (cv. Arka Kalyan) stored under ambient condition

Treatments	Taste and flavour					Mean
	Storage (Days)					
	Initial	30	60	90	120	
T_1	7.80	7.68	7.53	7.58	7.43	7.61
T_2	7.85	7.80	5.13	7.63	7.60	7.20
T_3	7.83	7.78	7.63	7.53	7.47	7.65
T_4	7.87	7.73	7.60	7.57	7.27	7.61
T_5	7.78	7.67	7.53	7.50	7.37	7.57
T_6	7.90	7.77	7.60	7.43	7.43	7.63
T_7	7.95	7.80	7.63	7.53	7.23	7.63
T_8	8.02	7.90	7.80	7.78	7.63	7.83
T_9	7.68	7.40	7.37	7.38	7.47	7.46
T_{10}	7.87	7.85	7.67	7.55	7.50	7.69
T_{11}	8.00	7.95	7.73	7.68	7.57	7.79
T_{12}	7.82	7.68	7.57	7.55	7.10	7.54
Mean	**7.86**	**7.75**	**7.40**	**7.56**	**7.42**	**7.60**
S. Em±	0.08	0.10	0.73	0.06	0.15	0.22
CD@5%	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Note: Values with the same superscripts in same column are not significantly different by Duncan Multiple Range Test at $p \leq 0.05$.

T_1 – Control	T_7 – Pre-harvest spray of CCC 2500 ppm at 90 DAT
T_2 – Pre-harvest spray of SA (2 mM) at 60 + 90 DAT	T_8 – Pre-harvest spray of SA (2 mM) at 60+90 DAT + CCC 2500 ppm at 90 DAT
T_3 – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) at 60 + 90 DAT	T_9 – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) at 60 + 90 DAT+CCC 2500 ppm at 90 DAT
T_4 – Pre-harvest spray of azoxystrobin (0.1%) at 60 + 90 DAT	T_{10} – Pre-harvest spray of azoxystrobin (0.1%) + CCC 2500 ppm at 90 DAT
T_5 – Pre-harvest spray of SA (2 mM) + zoxystrobin (0.1%) at 60+90 DAT	T_{11} – Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT + CCC 2500 ppm at 90 DAT
T_6 – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT	T_{12} – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT + CCC 2500 ppm at 90 DAT

Table 17: Effect of seedling dip and pre-harvest sprays on overall acceptability of onion bulbs (cv. Arka Kalyan) stored under ambient condition

Treatments	Overall acceptability					Mean
	Storage (Days)					
	Initial	30	60	90	120	
T_1	7.95^{bcd}	7.79^{de}	7.63^{de}	7.56	7.23^{b}	7.63
T_2	7.84^{de}	7.83^{de}	7.73^{bcd}	7.56	7.53^{a}	7.70
T_3	7.91^{cde}	7.85^{cde}	7.70^{bcd}	7.61	7.40^{ab}	7.69
T_4	7.82^{de}	7.83^{de}	7.67^{cde}	7.57	7.23^{b}	7.62
T_5	7.92^{cd}	7.89^{cd}	7.73^{bcd}	7.64	7.33^{b}	7.70
T_6	7.87^{cde}	7.87^{cde}	7.73^{bcd}	7.48	7.30^{b}	7.65
T_7	8.06^{b}	7.78^{de}	7.70^{bcd}	7.49	7.37^{ab}	7.68
T_8	8.20^{a}	8.00^{ab}	7.80^{ab}	7.63	7.40^{ab}	7.81
T_9	7.79^{e}	7.65^{f}	7.57^{e}	7.49	7.37^{ab}	7.57
T_{10}	7.99^{bc}	7.96^{bc}	7.77^{bc}	7.64	7.33^{b}	7.74
T_{11}	8.25^{a}	8.09^{a}	7.90^{a}	7.71	7.53^{a}	7.90
T_{12}	7.78^{e}	7.76^{ef}	7.63^{de}	7.57	7.23^{b}	7.60
Mean	**7.95**	**7.86**	**7.71**	**7.58**	**7.36**	**7.69**
S. Em±	0.00	0.05	0.02	0.02	0.06	0.03
CD@5%	**0.13**	**0.11**	**0.11**	**NS**	**0.19**	**0.11**

Note: Values with the same superscripts in same column are not significantly different by Duncan Multiple Range Test at $p \leq 0.05$.

T_1 – Control	T_7 – Pre-harvest spray of CCC 2500 ppm at 90 DAT
T_2 – Pre-harvest spray of SA (2 mM) at 60 + 90 DAT	T_8 – Pre-harvest spray of SA (2 mM) at 60+90 DAT + CCC 2500 ppm at 90 DAT
T_3 – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) at 60 + 90 DAT	T_9 – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) at 60 + 90 DAT+CCC 2500 ppm at 90 DAT
T_4 – Pre-harvest spray of azoxystrobin (0.1%) at 60 + 90 DAT	T_{10} – Pre-harvest spray of azoxystrobin (0.1%) + CCC 2500 ppm at 90 DAT
T_5 – Pre-harvest spray of SA (2 mM) + zoxystrobin (0.1%) at 60+90 DAT	T_{11} – Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT + CCC 2500 ppm at 90 DAT
T_6 – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT	T_{12} – Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT + CCC 2500 ppm at 90 DAT

Plate 8. Panelists conducting sensory evaluation of onions

5. DISCUSSION

Onion (*Allium cepa* L. 2n=16), is one of the most important vegetable crop species belonging to Alliaceae family. As a commercial vegetable crop, it is widely grown and exported from India. India stands first in area and second in production of onion, while the productivity is lower when compared the other major onion growing countries. Even though, some of the institutions like, Directorate of onion and garlic research, Rajgurunagar, (Pune) Indian Institute of Horticulture Research, Bangalore and National Horticultural Research and Development Foundation, Nashik, have intensively working on onion productivity and post harvest handling of the same. Like other produce, onions remain metabolically active even after harvest which inturn reduces the storage life. Despite the achievements in production technology, the post harvest losses during storage still pose a great problem. The post harvest losses due to sprouting, rotting, and physiological loss in weight pose great problem in storage of onion. Post harvest loss (sprouting, rotting etc), caused by pre and post harvest mismanagement is a serious threat to the interest of growers and consumers. In India, post harvest losses of onion could be as high as 40-50 % (Nandasana *et al.,* 1998). Improper pre and post harvest practices may cause deterioration of onion produce.

Onion is a seasonal crop, *rabi* season crop yields 50-60 per cent production whereas the *kharif* and late *kharif* season crop covers rest of the production. In order to meetout the requirements in offseason and to check glut during excess production storage assumes paramount importance. However, significant losses in terms of quantity and quality of onion bulbs occur in storage. Small land holding of the poor farmers, lack of knowledge about the scientific handling of onion after harvest and high cost demanding improved storage structures *etc*. are the constraints in scientific storage of onion. However, onion can be stored for a short period to balance its demand and supply in the market provided the bulbs are thoroughly cured before storage. There is a problem of sprouting, rotting, weight loss and bulbs tend to lose chemical constituents when stored in an environment of high temperature and humidity. High humidity coupled with high temperature favors sprouting and rotting of bulbs and ultimately leads to the loss of keeping quality, thereby reducing their post harvest storage life.

The axillary buds of the onion bulbs sprout on release of apical dominance, since the apical bud ceases to function during storage, if the environmental conditions are favourable. Many buds sprout and decrease the quality of bulbs. In addition, latent infection carried from the field results in bulb rotting and physiological activity *i.e.,* respiration and transpiration contribute for increase in PLW. A number of growth regulators and chemicals have been tried to minimize the above said problem (sprouting, rotting and PLW) during storage. However, the entry and penetration of these substances to the axillary buds is often difficult in onion and hence often the desired effects are not realized.

Keeping this in view, attempts have been made in the present investigation to study the effect of pre-harvest application of chemicals with respect to sprouting, rotting, physiological loss in weight, total loss, black mould and biochemical changes during storage. The results obtained on these aspects are discussed in this chapter.

5.1 Yield (t/h), number of bulbs/kg and bulb diameter (mm)

The effect of field application of SA, azoxystrobin and CCC on yield was found to be significant. In the present investigation, treatments involving combined application of chemicals such as in T_{11} (Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) (48.56 t/ha), T_{10} (Pre-harvest spray of azoxystrobin (0.1%) at 60 + 90 DAT and foliar spray CCC 2500 ppm 90 DAT) (48.10 t/ha), T_8 (Pre-harvest spray of salicylic acid (2 mM) at 60 + 90 DAT and foliar spray of cycocel 2500 ppm 90 DAT) (48.07 t/ha)and T_5 (Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT) (48.31 t/ha) are found to enhance yield. Increase in yield due to combined application of these chemicals clearly indicates the existence of synergistic effect among them. Several workers have shown significant increase in bulb yield due to the application of growth regulators (Singh *et al.,* 1993, Nirmal *et al.,* 1994 and Ibarra *et al.,* 1994).

In general, the bulb yield depends on the accumulation of photo assimilates and partitioning in to different parts of the plant. Bulb yield of onion was strongly influenced by the application of different growth regulators indicating the role of these

chemicals in increasing the bulb yield through their effect on various morpho-physiological and biochemical traits. The growth regulators are capable of partitioning of dry matter in plants, there by bringing on improvement in the yield (Reddy 2009, Patil, 1994, Chetti, 1991 and Chandrababu *et al.,* 1995). Plant growth regulator-induced higher yields are mainly due to altered photosynthates, distributive patterns within the plant by coordinating plant processes to synthesize maximum dry matter and portioning the major quantum of this increased dry matter into effective yield contributing factors. The growth regulator cycocel is known to alter the source-sink relation in the plant and directly or indirectly relocate carbohydrate resource and improve the translocation of photosynthates resulting in enhanced yield (Grewal *et al*. 1993). Similar results were reported by Maiti *et al.* (1972). These results confirm the earlier findings of Memane *et al.* (2008), Singh *et al.* (2008), Gasti *et al*. (2011c) and Anbukkarasi *et al.* (2011).

Foliar application of SA affects the plant water relation and photosynthetic rate. Exogenous application of SA increased net photosynthetic rate, internal CO_2 concentration and water use efficiency in *Brassica juncea* (Fariduddin *et al*., 2003). In addition, exogenous application of SA known to affects leaf and chloroplast structure (Uzunova and Popova, 2000), stomatal closure (Mateo *et al*., 2004; Melotto *et al*., 2006), chlorophyll and carotenoid contents (Rao *et al*., 1997 Chandra and Bhatt, 1998; Fariduddin *et al*., 2003), and the activity of enzymes such as RuBisCO (ribulose-1,5 bisphosphate carboxylase/oxygenase) and carbonic anhydrase (Pancheva and Popova, 1998; Slaymaker *et al*., 2002). A lower concentration of SA (10 µM) improves the photosynthetic net CO_2 assimilation in mustard seedlings. As PN increases, carboxylation efficiency, chlorophyll content, and the activities of carbonic anhydrase and nitrate reductase are also up-regulated (Fariduddin *et al*., 2003). It was suggested that the beneficial effects of this low dose of SA in photosynthesis might be related to the prevention of AUX oxidation by SA, since elevated AUX levels increases PN and nitrate reductase activity (Ahmad *et al*., 2001).

Again, it has been observed that the effects of exogenous SA on photosynthesis parameters differ depending on the dose and plant species tested. In the present investigation, least yield was observed with the treatments T_3 (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid @ 2 mM at 60 + 90 DAT) (44.84 t/ha),T_6 (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid @

2 mM followed by foliar spray of azoxystrobin @ 0.1% at 60 + 90 DAT) (45.52 t/h), T_9 (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid (2 mM) at 60 + 90 DAT and foliar spray CCC 2500 ppm 90 DAT) (46.20 t/ha) and T_{12} (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) (44.24 t/h). As high SA concentrations cause a reduction in the photosynthetic rate (PN) and RuBisCO activity in barley plants (Pancheva *et al*., 1996), and reduced chlorophyll contents in cowpea, wheat, and Arabidopsis (Rao *et al*., 1997; Chandra and Bhatt, 1998; Moharekar *et al*., 2003). Exogenous SA induces alterations in leaf anatomy that consist of a reduced width of the adaxial and abaxial epidermis, and of the mesophyll tissue. Such changes correlate ultra structurally with an increase in chloroplast volume, swelling of grana thylakoids, and coagulation of the stroma (Uzunova and Popova, 2000). Thus, the diminished photosynthetic activity at high concentrations of SA is due to its effects on the thylakoid membranes and light-induced reactions linked to them.

The application azoxystrobin could have enhanced total nitrate assimilation in more nourished plants under less favourable light conditions, resulting in better crop growth and productivity. This hypothesis is also supported by the findings of Glaab and Kaiser (1999), who found that KROM strobilurin on spinach-discs, is able to activate NADH–nitrate reductase (NR) (EC 1.6.6.1) above its normal activation state, both in the dark and in the light. The NR catalyzes the first stage of nitrate assimilation, representing the main enzyme involved in nitrogen metabolism in plants, in particular in nitrate assimilation (Campbell, 2002).

With respect to number of bulbs per kg and bulb diameter, significant difference was noticed. Maximum number of bulbs per kg and minimum diameter was observed in treatment T_8 (Pre-harvest spray of salicylic acid @ 2 mM at 60 + 90 DAT and foliar spray of CCC 2500 ppm 90 DAT), whereas treatment T_{12} (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) exhibits minimum number of bulb per kg with maximum diameter. According to El-mergawi and Abdel-Wahed (2004), low dose of SA significantly increased the total carbohydrate content and higher dose decreased it in onion. This could be the reason why SA treated plants showed

maximum number of bulb per kg and minimum diameter. Whereas foliar application of CCC (1500 ppm) increased the seed yield, number of seeds per pod and 100 seed weight as compared to control in soybean (Kamal *et al.*, 1995). Similar results were also obtained by Jayakumar and Thangaraj (1991) in groundnut with the foliar application of Mepiquat chloride.

5.2 Physiological loss in weight (PLW)

Physiological loss in weight refers to loss in weight of the produce due to physiological process such as transpiration and respiration. Transpiration is a mechanism in which water is lost due to difference in the vapour pressure of the water in the atmosphere and the transpiring surface. Whereas respiration is a catabolic activity involving oxidation of complex substrates resulting in the formation of CO_2 molecule which is evolve into the atmosphere. The rate of water loss is dependent upon the type of crop evaluated, and was greatly related to physiological and morphological characteristics of the commodity and expected shelf life of the commodity in a given environmental condition.

The minimum loss in weight of bulb during storage is considered to be one of the desirable factors to increase storage life. In general, PLW of any produce increases with advancement in storage. Likewise in the present investigation also there is gradual increase in PLW of stored onion bulbs was observed irrespective of treatment imposed. However, combined application of growth regulators and chemicals significantly reduced the cumulative physiological loss in weight in storage compared to control. The treatment T_{11} (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid @ 2 mM at 60 + 90 DAT) (11.62%), T_6 (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid @ 2 mM followed by foliar spray of azoxystrobin @ 0.1% at 60 + 90 DAT) (12.43 %) and T_{12} (12.88%) are found be elite treatments in reducing the PLW with progress in storage period of 120 days. This could be due to the combined effect of SA, azoxystrobin and CCC.

The fungicide azoxystrobin which helped in controlling the black mould responsible for decay of onion bulbs and CCC a growth retardant substance reduces the respiration rate of bulbs, which in turn reduces the loss of moisture from the bulbs. The

chemical must have played a vital role in modifying the rate of gaseous exchange that takes place through the surface of the bulbs by changing the ratio of carbon dioxide and oxygen inside the bulbs, thus minimising the respiration and transpiration rate of the bulbs in turn must have reduced the rate of moisture loss and ultimately prevented the loss in weight (Vijayakumar *et al*., 1987). Similar findings were obtained by Singh and Dhankhar (1995) in onion. Salicylic acid as an electron donor produces free radical which prevents normal respiration and SA can also decrease respiration rate and bulb weight loss by stoma closing (Zheng and Zhang, 2004, Freddo *et al.* 2013). SA increases the antioxidant activity and causes delay in the onset of hydrolysis of structural cell components. It also decrease the rate of transpiration which is associated with reduction in hydrolytic cell wall enzyme activity which is in turn is greatly influenced by SA. Similar results were obtained by Shafiee *et al*. (2010) in strawberry, Kazemi *et al*. (2011) in apple, Barman and Asrey (2014) in mango and Awad (2013) in peach.

5.3 Respiration rate

Even after harvest, the produce continues the process of respiration as are alive which is a characteristic of all living things. Respiration is the metabolic process in which stored organic materials are broken down with a release of energy as vital heat. Thus produced energy can be captured as high energy bonds in compounds that could be used by cell in subsequent reactions, or it can be lost in the form of heat. The energy and organic molecules produced during the process of respiration are utilized by other metabolic process to maintain the health of the commodity (Saltveit, 1993).

The deterioration rate of harvested commodities is generally in proportion to their respiration rate. Respiration determines the rate of metabolic processes which in turn have a direct impact on eating quality characteristics such as firmness, sugar content, pungency and overall flavour (Crowther *et al*., 2005; Terry *et al*., 2005). Commodities with high rate respiration possess short storage life (lettuce, broccoli, peas spinach etc.) in comparison to commodities with low rate of respiration are usually having relatively long storage life (apple, potato, onions etc.). With increased temperature the respiration rate of onion rises more slowly than it does in most of the

crops. Respiration however, results in continuous loss of stored food (dry matter) and in production of heat. Respiration is low in dormant onions.

In the present investigation a gradual increase in rate of respiration was noticed irrespective of treatments imposed at all the successive stages of the storage. Initially mean rate of respiration was low *i.e*. 12.55 ml/CO_2/kg/h, increased to 13.95 ml CO_2/kg/h, 17.00 ml CO_2/kg/h, 18.53 ml CO_2/kg/h, and 20.02 ml CO_2/kg/h at 30, 60, 90 and 120 DAS respectively. However, the low rate of respiration was observed in the treatment T_3 (15.29 ml/CO_2/kg/h), T_6 (15.37 ml/CO_2/kg/h) T_{11} (15.37 ml/CO_2/kg/h) and T_9 (15.38 ml/CO_2/kg/h).

In the present experiment, treatments containing SA are able to decrease the respiration rate of onions with prolonged storage. It may be the effect of SA as it has been reported to effectively reduce the respiration rate in several fruit such as Banana and Apple (Srivatsava and Dwivedi, 2010 Mo *et al*., 2008). SA as a signal triggers the induction of cyanide resistance respiration in plant cells by affecting the alternative oxidase (AOX) enzyme activity (Raskin, *et al*., 1989). In horticultural crops, SA affects AOX activity leading to decrease in the harmful effects of different post-harvest oxidative stresses such as chilling injury, prevents fermentation, and maintains low respiration rates and decreases fruit ripening and senescence rates. Respiration of harvested crops is highly dependent to ethylene production and activity and any factor increasing the production and activity of ethylene leads to increases in respiration and consequently increases the senescence rate. Effect of SA in decreasing the respiration rate is mainly due to it's negative effects on ACC, ACO, PG, PME, cellulase and antioxidant enzymes leading to decrease in ethylene production and action (Mohammadreza and Morteza, 2010). Zhang *et al*, 2003 reported a similar effect on kiwi fruit treated with acetyl salicylic acid (ASA).

However, higher rate of respiration was noticed in treatment T_1 (Control) (19.34 ml CO_2/kg/h). Uncontrolled sprouting and rotting might have resulted in increased rate of respiration.

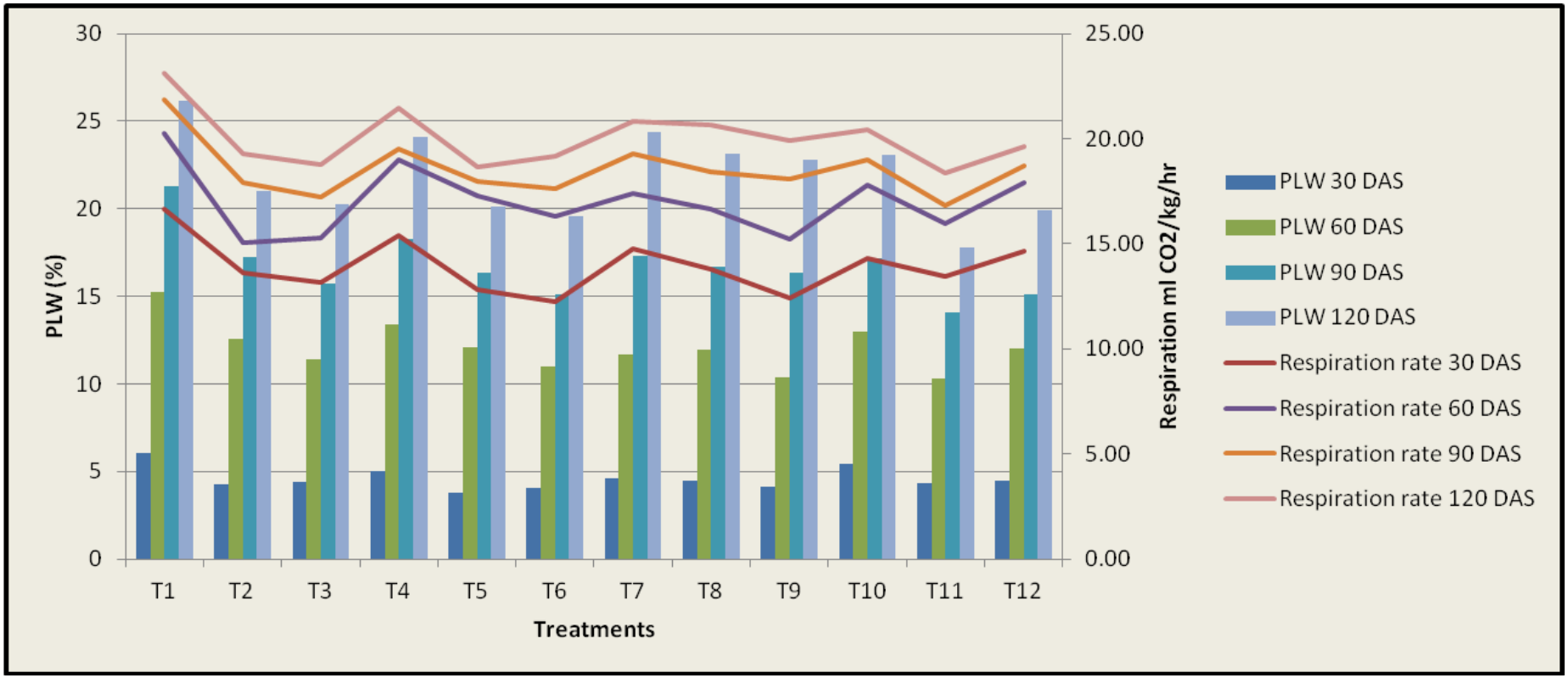

Fig. 1: Graph showing effect of field application of SA, azoxystrobin and cycocel on physiological loss in weight (PLW) and respiration rate of onions during storage

T_1 - Control
T_2 - Pre-harvest spray of SA (2 mM) at 60 + 90 DAT
T_3 - Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2mM) at 60 + 90 DAT
T_4- Pre-harvest spray of azoxystrobin (0.1%) at 60 + 90 DAT
T_5 - Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT
T_6 - Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT
T_7 – Pre-harvest spray of CCC 2500 ppm at 90 DAT
T_8 - Pre-harvest spray of SA (2 mM) at 60 + 90 DAT + CCC 2500 ppm at 90 DAT
T_9 - Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) at 60 + 90 DAT+ CCC 2500 ppm at 90 DAT
T_{10} – Pre-harvest spray of azoxystrobin (0.1%) + CCC 2500 ppm at 90 DAT
T_{11} - Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT + CCC 2500 ppm at 90 DAT
T_{12} - Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT + CCC 2500 ppm at 90 DAT

5.4 Sprouting

Sprouting is the major factor limiting the storability of onion (*Allium cepa*) bulbs (Chope *et al*., 2006). At harvest, onion bulbs are usually dormant. After harvest onion enters into a state of rest referred as dormancy during which onion bulbs remain inactive physiologically even though favorable environmental conditions are existing. It is true that dormant bulbs possess least rate of respiration and appeared to change little, but now known that within the bulb there is continuous process of growth, very slow at first but gradually accelerating (Brewester, 1987). Sprouting is initiated by two factors: (1) induction of cytokinin with the decrease in abscisic acid (ABA) (Miedema and Kamminga, 1994; Abeles *et al*., 1992) and (2) stress such as wound (Miedema, 1994b) or heat shock (Miedema, 1994a).

Sprouting occurs when leaf primordial that are produced in stored onion bulbs develop green leaves, rather than the scale leaves, which elongate and eventually protrude from the neck of the bulb (Abdalla and Mann, 1963). The growth rate of the sprout inside the bulb varies according to cultivar and storage environment (temperature and RH) (Chope *et al*., 2006). Temperature has profound effect on the dormancy period and storage life of onion bulbs (Komochi, 1990; Ramin, 1999). Ultimately Sprouting is the eventual result, and accompanying rise in respiration rate leads substantial heat output. The rate at which dormancy is lost based on several factors. Depending on genotype and storage conditions sprout growth is initiated after a certain period of storage (Komochi, 1990). Hormonal control involving a gradual increase of the ratio of sprouting promoters to inhibitors may underlie the loss of dormancy with time (Gubb and MacTavish, 2002). It leads transfer of both dry matter and water from edible fleshy scales in to the sprouts resulting in increased shriveling of bulbs, consequently onion bulbs lose marketable quality (Kukanoor *et al.,* 2005).

In the present investigation, the mean per cent sprouting was found to be minimum for treatments T_{12} (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) (2.26%), T_{11} (Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray

90 DAT) (2.82%), T_9 (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid @ 2 mM at 60 + 90 DAT and foliar spray cycocel 2500 ppm 90 DAT) (3.47%) and T_5 (Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT) (3.55%).

From the above observation, it is clear that use of combined chemical was found to be effective in sprout suppression. This clearly indicates the existence synergy among the chemicals and each chemical contributes its own share for sprout suppression.

Growth regulator cycocel prolong the dormancy for longer period after harvest. This could be attributed to reduced neck thickness in sprayed bulbs and by way of minimised cell division and due to the removal of apical dominance inhibiting sprout initiation. The results of the present investigation are in conformity with the findings of Bhujbal and Patil (1978), Singh and Dhankhar (1995), Chaobasingh and Bhattacharjee (1998) and Anbukkarasai *et al.,* (2013).

Fungicide azoxystrobin is known to influence some aspects of plant physiology, likely through the interaction with electron transfer in plant mitochondria (Barlett *et al*., 2002). Dose response experiments revealed that strobulin shifted the hormonal balance, favouring cytokinin as opposed to ethylene, and causing up to a two fold increase in endogenous level of abscisic acid (ABA) a harmone which checks the growth. The phytoharmone ABA plays an important role in many physiological process in plants. This harmone is necessary for regulation of several events during late seed development, and is crusial for the response to environmental stresses (Anatonio *et al.,* 2012).

SA inhibited mitotic index in onion root cells (Trushin *et al.,* 2013).It is also known to inhibit the process of seed germination the authors Anandhi and Ramanujam (1997), Asthana and Srivastava (1978), Negi and Prasad, (2001) reported an inhibitory effect SA on germination of black gram, maize and soya bean respectively. However, SA at higher concentration results in inhibitory effect of SA on plant growth in tomato, maize, and lupine as reported by Kord and Hathout (1992), El- Wahed *et al.* (2006) and

Habba (2003). SA treated plants accumulated high concentration of ABA (Sakhabutdinova *et al.*, 2003).

5.5 Rotting

Microbial spoilage is a major constraint in storability of onion during storage. The most serious loss arises from storage rots due to various diseases caused by bulb rotting fungi (Jones and Mann, 1963). About 15 different fungal species and 5 bacterial species are found responsible for the onion diseases in the storage and transit all over the world. The loss due to these diseases is considerable and may go up to 40 per cent (Aiyer, 1980). In storage, various diseases caused different kind of micro organism destroy the onions, they multiply and infect the bulb surface when congenial conditions prevail. Pre-harvest application of fungicides and chemicals to control rotting is a fairly a common practice. Such treatments can improve the storage life of bulbs by preventing pathological disorders. Storage loss of onions in variety Punjab-48 was studied by Saimbhi and Randhawa (1982) and found losses due to rotting in storage to be greatest in large bulbs and least in the small ones.

In the present investigation, bulb rotting shows a gradual increase at all the successive stages of the storage. The mean per cent rotting was found to be 1.33 per cent, 2.60 per cent, 3.85 per cent and 5.21 per cent at 30, 60, 90 and 120 DAS respectively. Numerically least rotting was noticed in the treatment T_5 (Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT) (1.87%), T_{11} (Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) (2.07%), T_8 (Pre-harvest spray of salicylic acid @ 2 mM at 60 + 90 DAT and foliar spray of CCC 2500 ppm 90 DAT) (2.12%) and T_{10} (Pre-harvest spray of azoxystrobin (0.1%) at 60 + 90 DAT and foliar spray CCC 2500 ppm 90 DAT) (2.54 %). On contrary to this treatment T_{12} (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) (4.36%) take over the next place after treatment T_1 (Control) (7.09%) which could not be fully understood and might be due to different pre and post harvest factors and also due to the presence large sized bulb are usually susceptible for rotting (Saimbhi

and Randhawa, 1982). Combination of chemicals was found to be more effective in decreasing the per cent rotting rather using them alone indicating that there is an enhanced rate of control in rotting as all the chemicals are effective in checking rotting by different mode of action. Exogenous application of SA at nontoxic concentrations to susceptible fruits and vegetables could enhance resistance to pathogens and control post-harvest decay (Asghari *et al*., 2009; Asghari *et al*., 2007; Babalar *et al*., 2007). MeSA triggers disease resistance and mediates the expression of defense related genes in neighboring plants and in healthy tissue of infected plants (Shulaev *et al*., 1997). Some researches indicate that SA also exhibits direct antifungal effects against pathogens. Plants protect themselves against the pathogen attacks by activating some kinds of defense mechanisms such as local acquired resistance (LAR) and systemic acquired resistance (SAR) (Vlot *et al*., 2009). Salicylates are a major component in the signal transduction pathways of plants playing an important role in disease resistance (Park *et al*., 2007). Once plant defense responses are activated at the site of infection (LAR), a systemic defense response is often triggered in distal plant parts to protect these undamaged tissues against subsequent invasion by the pathogen. This long-lasting and broad-spectrum induced disease resistance is referred to as SAR and is characterized by the coordinate activation of a specific set of PR-genes, many of which encode for proteins with antimicrobial activity (Durrant & Dong, 2004).

Azoxystrobin is one among the strobilurin class of systemic fungicides. Inhibition of mitochondrial respiration is an important mode of action for inhibiting pathogen growth. It has the ability to inhibit electron transfer in fungal mitochondria by binding at a specific site on *cytochrome b*. The result of this activity is the cessation of normal energy production (ATP) within the cells, which results in cell death. Evidence of this on fungi can be observed in spore mortality, mycelial collapse and inhibition of sporulation or disruption of other vital stages of fungal development (Harrisson and Tedford, 2002). It is a broad spectrum fungicide with protectant, curative, eradicant and systemic properties. It travels through leaf surface to leaf tip and growing edges (Arreaza and Hernandez, 2001). It shows a unique broad spectrum of disease control and activity against Oomycetes, Ascomycetes, Basidiomycetes and Deuteromycetes.

None of the currently available commercial fungicides combines this breadth of spectrum with high levels of intrinsic activity at low rates (Anand *et al*., 2010).It moves into the tissues from the site of application through diffusion. Inside the tissues Azoxystrobin helps in controlling the disease through translaminar and systemic movement (Vincelli, 2002). Even the growth retardant cycocel is also known to decrease per cent rotting in onion. Crop sprayed with cycocel (lihocin) @ 2500 ppm on 75 and 90 days after transplanting (Anonymous, 2004).

5.6 Black mould

Black mould of onions is caused by the fungus *Aspergillus niger* van Tieghem. It is high temperature favouring fungus for its growth and optimum temperature range for growth is 28-34°C. Warmth and moisture favour development of the disease (Maude *et al.* 1984). Although the disease can occasionally be seen in the field at harvest, black mould is primarily a postharvest disorder and can cause extensive losses in storage under tropical conditions (Thamizharasi & Narasimham 1992).

Black mould was first recorded causing a storage rot of onions in New Zealand in 1959 (Brien *et al*. 1959) and at that time it was thought to be of little economic importance (Dingley 1969). Over the past decade black mould has become of increasing importance to onion growers. It not only reduces the value of the product but also some causes human health hazard by way producing aflotoxin. *Aspergillus niger* is common as a saprophyte in soil and on decaying plant material. The fungus can be seed-borne in onions, and up to 100 per cent of seed lots in Sudan were found to be naturally infested (El-Nagerabi and Ahmed, 2001).

In the present investigation, the incidence of black mould increased with prolong storage of 120 days. The mean values for the disease incidence varies from 0.75 per cent to 4.45 per cent during the experiment. The least mean values was recorded for the treatment T_{12} (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) (1.63 %) followed by treatment T_{11} (Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) (1.74%), T_{10} (Pre-harvest spray of azoxystrobin (0.1%) at 60 + 90 DAT and foliar spray cycocel 2500 ppm 90 DAT) (2.01%) and T_4 (Pre-harvest spray of

azoxystrobin @ 0.1% at 60 + 90 DAT) (2.05%). Azoxystrobin has a novel mode action (Hewitt, 1998) and the role of application at different time intervals and at higher concentration (0.1%) played a major role in controlling black mould in the present investigation. Its fungicidal activity results from inhibiting the mitochondrial respiration of higher fungi, which is achieved by prevention of electron transfer between *cytochrome-b* and *cytochrome-c* (Becker *et al*., 1981). Alphanso trees sprayed azoxystrobin @ 2 ml/L suppressed the development of anthracnose (Sundaravadana *et al*., 2006) Similar results obtained by Xuequn *et al.* (2012) in mango.

The fungicide in combination with SA and CCC proved best in reduction of black mould incidence. As SA induce SAR which might have helped azoxystrobin in minimizing the disease incidence and CCC a growth retardant substance, reduces the respiration rate of bulbs, which in turn reduces the loss of moisture from the bulbs thus creating unfavorable environment for growth of pathogen.

In treatment T_1 (Control) progressive incidence of the disease was noticed 6.67 per cent at 120 DAS. This clearly indicates the efficacy of the field application of chemicals over the untreated control.

5.7 Marketable bulbs

Availability of maximum quantity of healthy and sound bulbs at the end of storage period is of paramount importance for better sale and to get good returns. Storage life of onions depends on many factors such as cultivar and pre- and post-harvest treatments influencing the quantum of marketable bulb.

In the present study, the mean marketable bulb ranges from 92.42 per cent in the first 30 DAS to 69.51 per cent in the successive 120 DAS. The maximum per cent marketable bulbs at the end of storage period was obtained in the treatment T_{11} (Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) (85.54%) at the end 120 DAS followed by T_5 (Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT) (83.52%), T_9 (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid @ 2 mM at 60 + 90 DAT and foliar spray CCC 2500 ppm 90 DAT) (82.91%), T_6 (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid @ 2 mM followed by foliar spray of azoxystrobin @ 0.1% at 60 + 90 DAT) (82.36%) and T_{12} (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of

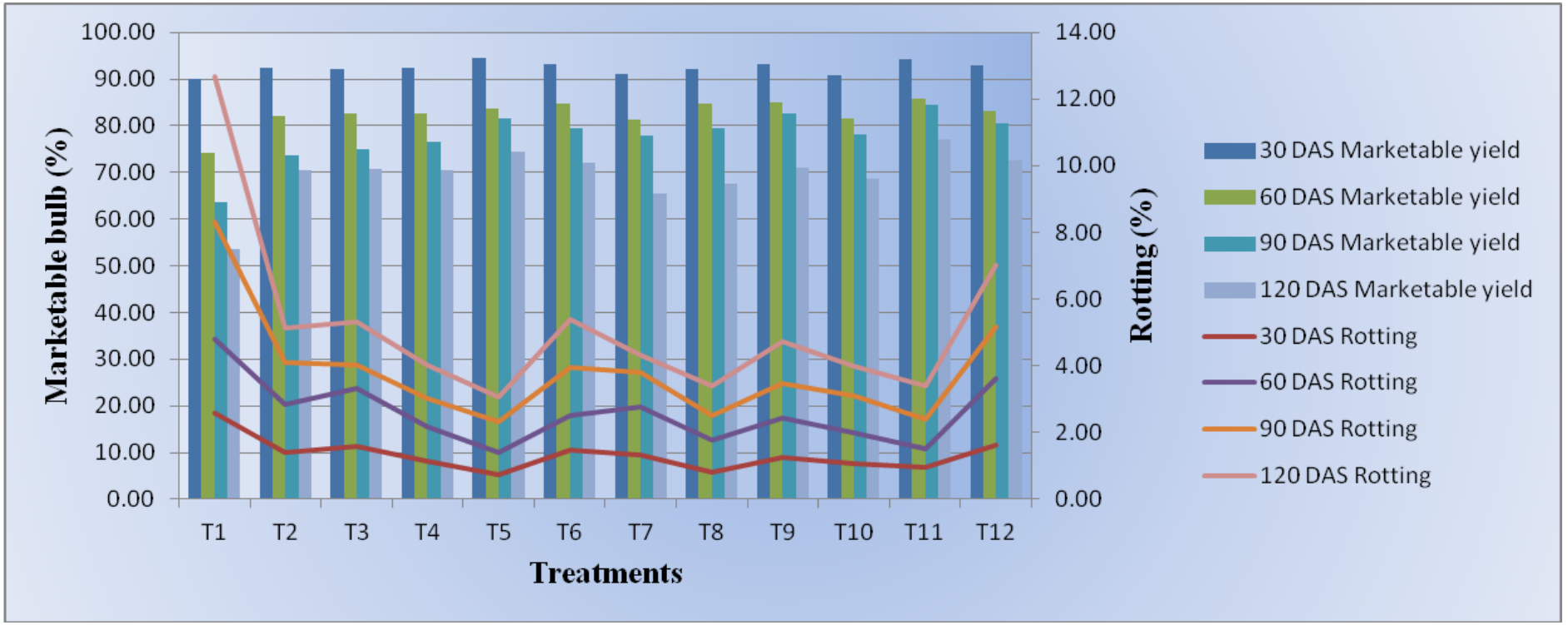

Fig. 2: Graph showing effect of field application of SA, azoxystrobin and cycocel on marketable bulbs and rotting in onions during storage

T_1 - Control
T_2 - Pre-harvest spray of SA (2 mM) at 60 + 90 DAT
T_3 - Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2mM) at 60 + 90 DAT
T_4- Pre-harvest spray of azoxystrobin (0.1%) at 60 + 90 DAT
T_5 - Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT
T_6 - Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT
T_7 – Pre-harvest spray of CCC 2500 ppm at 90 DAT
T_8 - Pre-harvest spray of SA (2 mM) at 60 + 90 DAT + CCC 2500 ppm at 90 DAT
T_9 - Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) at 60 + 90 DAT+ CCC 2500 ppm at 90 DAT
T_{10} – Pre-harvest spray of azoxystrobin (0.1%) + CCC 2500 ppm at 90 DAT
T_{11} - Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT + CCC 2500 ppm at 90 DAT
T_{12} - Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT + CCC 2500 ppm at 90 DAT

salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) (82.32%), This may be attributed to minimum physiological loss in weight (%), per cent rotting and per cent sprouting in these treatments. These results are in conformity with the findings of Blanco and Oliveira (1971) and Kepkawa (1966) in onion.

As already discussed about the effect of using combination of chemicals on yield, rotting, sprouting and on PLW of the stored onion bulbs. For all attributes the treatment T_{11}(Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) was found be the best. Again each chemical has its own contribution for recording maximum quantity of marketable bulbs. As SA is known to influences the yield by enhancing the photosynthesis efficiency and reducing diseases by increasing the firmness and plant metabolites. The results are in conformity with the findings of Kukanoor (2005) in onion, Wedge *et al*. (2007) in strawberry and Roback and Adamicki, (2007) in strawberry. Similarly another growth regulator cycocel is also known to alter the source-sink relation in the plant and directly or indirectly relocate carbohydrate resource and improve the translocation of photosynthates resulting in enhanced yield (Grewal *et al*. 1993). Similar results were reported by Maiti *et al.* (1972). However the fungicide azoxystrobin is a broad spectrum fungicide with protectant, curative, eradicant and systemic properties. It shows a unique broad spectrum of disease control and activity against Oomycetes, Ascomycetes, Basidiomycetes and Deuteromycetes. None of the currently available commercial fungicides combines this breadth of spectrum with high levels of intrinsic activity at low rates (Anand *et al*., 2010). It moves into the tissues from the site of application through diffusion. Inside the tissues Azoxystrobin helps in controlling the disease through translaminar and systemic movement (Vincelli, 2002).

Minimum per cent marketable bulbs were noticed in the treatment T_1 (Control) which is mainly because of high rate respiration, moisture loss inturn resulting maximum loss in weight inaddition to this uncontrolled sprouting and rotting too contributing to reduced marketable bulbs.

5.8 Moisture

Post harvest water loss has a great impact on the bulb quality and is major cause for deterioration. Substantial water loss may result in a significant loss of fresh weigt, resulting in economic loss if the commodity is sold by weight. Slight moisture loss can cause substle quality changes in colour and texture, and when the critical moisture loss threshold is reached, more obvious deleterious changes in turgidity, firmness, discoloration, flavour and nutritional value can occur. Accelarated senescence increased pathogen invasion, and increased susceptibility to chilling injury have been reported to result from the weight loss. The rate of water loss varies widely among the fruits and vegetables, even when stored under same environmental condition (*i.e.* temperature and humidity). In general, tubers and bulbs tend to lose water at slower retain comparison to soft fruits while leafy vegetable are extremely vulnerable. Nevertheless, the quality of most of the fruits and vegetables declines very fast with only small moisture losses, in general, a loss of 3.0 per cent to 10.00 per cent may render a wide range of horticultural crops unacceptable for sale. In general moisture loss from produce occure mainly through transpiration which is as a result of difference in relative humidity between the commodity and the environment. It can be major cause for deterioration as it result in weight loss and shriveling changing both texture and appearance. Under low humidity and high temperature produce continue to loose moisture at relatively constant rate.

Moisture content and drymatter in plant are inversely related (Lisińska and Leszczyński, 1989). More the quantum of dry matter lesser the quantity of moisture in the bulbs (Lazić *et al*., 2000). The mean moisture content decreased from 84.71 per cent to 80.35 per cent during 120 DAS. Among the treatments, T_4 (Pre-harvest spray of azoxystrobin @ 0.1% at 60 + 90 DAT) (81.60%), showed less moisture content is due to the presence of high dry matter content in same treatment.

5.9 Dry matter

Dry matter content is the primary characteristic of onion bulb quality, determining, in part, the end use *(e.g.* as salad, cooking or dehydrated onions), storage life, pungency and firmness (Sinclair *et al*., 1995a). Onions with high dry matter content tend to be much firmer and store for longer periods before shoot growth and disease

incidence deplete the number of marketable bulbs (Darbyshire and Henry, 1979; Rutherford and Whittle, 1982; Suzuki and Cutliffe, 1989). Dry matter composition changes during storage. The structural carbohydrates in onion include the reducing fructose and glucose and non-reducing sucrose and series of oligosaccharides, the fructans (Darbyshire, 1978). These carbohydrates account for approximately 60 to 80 per cent of dry matter content (Rutherford and Whittle, 1982).

Higher moisture loss from the surface at ambient temperature caused maximum weight loss of onion. Hansen and Henriksen (2001) reported that moisture loss from outer surface of onion causes slight increase in dry matter during storage. Finding on this study was also supported by Vintila *et al.* (2014*)* who noted lowest weight loss of onion at cold condition than ambient condition. As with other vegetables, onions contribute to the intake of certain vitamins and minerals, but carbohydrates are the major nutrient fraction, many of which are components of dietetic fibre. Non-structural and soluble carbohydrates form a substantial part of onion dry matter, mainly as fructooligosaccharides (FOS) and monosaccharides (glucose, fructose and sucrose) (Darbyshire and Henry, 1979; Darbyshire and Henry, 1981; Jaime *et al*., 2001; O'Donoghue *et al.,* 2004; Susuki and Cutliffe, 1989).

In the present investigation, mean increase in drymatter content from 15.25 per cent to 19.64 per cent was observed during storage period of 120 days. The mean highest drymatter content was noticed in the treatment T_4 (Pre-harvest spray of azoxystrobin @ 0.1% at 60 + 90 DAT) (18.38%) followed by treatment T_9 (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid (2 mM) at 60 + 90 DAT and foliar spray CCC 2500 ppm 90 DAT) (17.59 %). The increase in dry matter content during the storage period could be attributed to the increase in chemical constituents and also decrease in the moisture content of the bulbs. Reduction in moisture content of the bulb and thereby the hydrolysis of sugar minimises and ultimately resulted in highest dry matter content due to accumulation of more sugar. The results obtained in the present study are in agreement with the result obtained by Mahadevaswamy (1984), Darbyshire (1978), and Singh and Dhankar (1995) in onion.

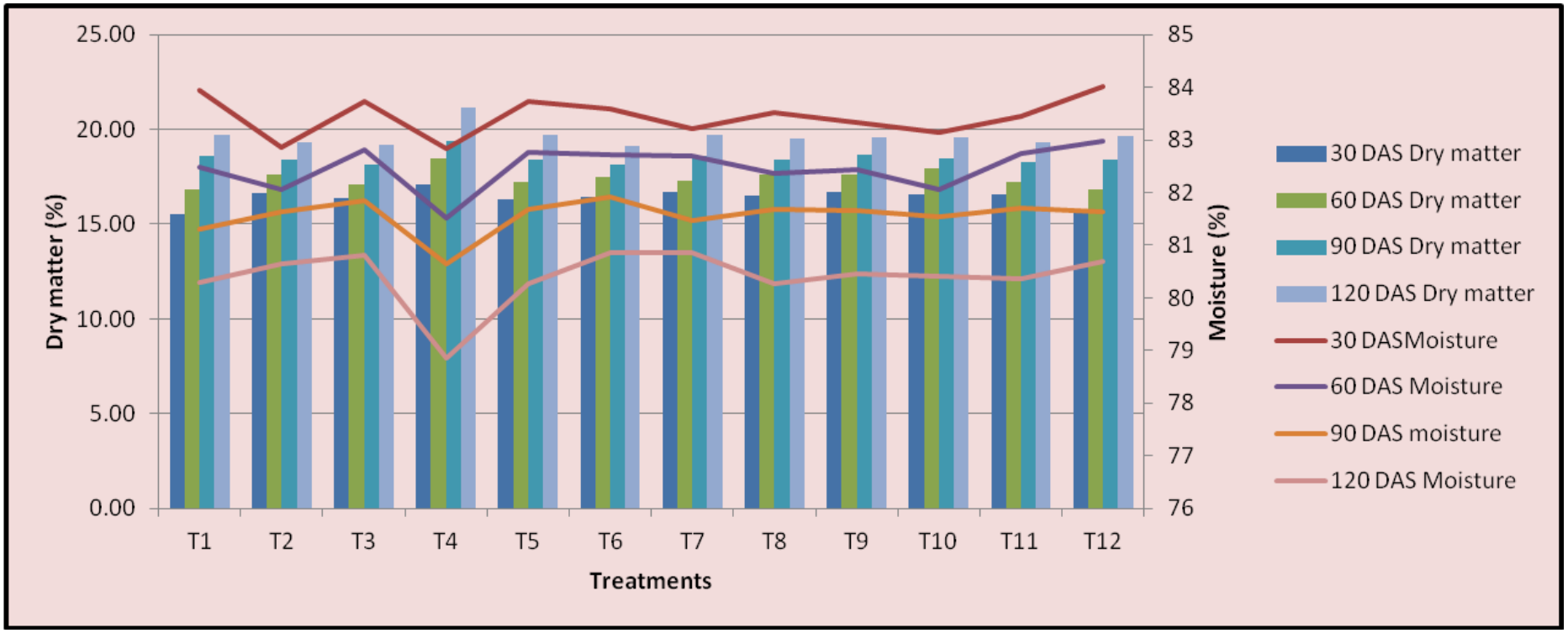

Fig. 3: Graph demonstrating relationship between dry matter and moisture content of onions during storage as influenced by field application of SA, azoxystrobin and cycocel

T_1 - Control
T_2 - Pre-harvest spray of SA (2 mM) at 60 + 90 DAT
T_3 - Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2mM) at 60 + 90 DAT
T_4- Pre-harvest spray of azoxystrobin (0.1%) at 60 + 90 DAT
T_5 - Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT
T_6 - Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT
T_7 – Pre-harvest spray of CCC 2500 ppm at 90 DAT
T_8 - Pre-harvest spray of SA (2 mM) at 60 + 90 DAT + CCC 2500 ppm at 90 DAT
T_9 - Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) at 60 + 90 DAT+ CCC 2500 ppm at 90 DAT
T_{10} – Pre-harvest spray of azoxystrobin (0.1%) + CCC 2500 ppm at 90 DAT
T_{11} - Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT + CCC 2500 ppm at 90 DAT
T_{12} - Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT + CCC 2500 ppm at 90 DAT

5.10 Firmness

Firmness is one of the most important quality attribute determining the product acceptability to the consumer. Loss of firmness is one of the main factor in limiting quality and the post harvest shelf life. Firmer bulbs store for longer period before shoot growth and disease incidence that deplete the number of marketable bulbs (Darbyshire and Henry, 1979; Rutherford and Whittle 1982; Suzuki, and Cutliffe, 1989).

In general bulb firmness decreases with increasing storage period. However in the present investigation treatments containing SA are able to retain bulb firmness with prolonged storage. Treatments like T_{12} (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) (122.72 N), T_{11} (123.98 N), T_9 (122.80 N), T_8 (120.02 N), T_6 (121.84 N), T_5 (121.09 N), T_3 (121.29 N) and T_2 (121.57 N) have succeeded in retaining the bulb firmness. This may be due to the reduced hydrolysis of soluble starch. Retention of fruit firmness as the result of SA treatment has been reported in several crops. It has been demonstrated that SA decreases ethylene production and inhibits cell wall and membrane degrading enzymes such as polygalacturonase (PG), lipoxygenase (LOX), cellulase and pectinemethylesterase (PME) leading to decreasing the fruit softening rate (Srivastava and Dwivedi, 2000; Zhang *et al.*,2003) thus maintaining firmness. Zhang *et al*. (2003) reported that rate of fruit ripening is related to internal SA concentration. Retention fruit firmness was associated with inhibition ACO enzyme activity. SA prevents fruit softening according to Srivastava and Dwivedi (2000), Zhang *et al*. (2003) and Wang *et al*. (2006). The authours found that rapid softening of fruits during ripening was simultaneous with rapid decrease in endogenous SA of fruits. SA affects cell swelling which leads to higher firmness of fruits (Zhang *et al*., 2003 and Shafiee *et al*., 2010). In addition Lam *et al*. (1987) stated that SA act as anti-transpiring chemical can retard moisture loss ascociated with pericarp browning of fruits. It may also inhibit senescent changes, which will consequently prolong shelf life of produce. MeSA, in a concentration dependent manner from 0 to 32 ml/L maintained firmness of kiwifruit during storage (Aghdam *et al.,* 2009). Srivastava and Dwivedi (2000) reported that in bananas treated with SA fruit softening markedly decreased. Zhang, *et al.* (2003) reported a positive correlation between fruit free SA content and firmness in kiwi fruit during ripening.

Solaimani *et al.* (2010) Post harvest application of MeSA in kiwi fruit decreased softening of fruits during storage. On contrary treatment T_1 (Control) (117.45 N) lost more firmness during prolong storage of 120 days which may be due to is due to huge loss of water and increased rate of respiration resulting in decreased firmness.

5.11 Total soluble solids

Total soluble solids is defined as the total of all the solids that dissolve in water, including sugars, salts, protein and organic acids, and the refractometer reading is the sum total of these. Thus, TSS is not a direct measure of sugar content and is unrelated to the perceived sweetness of some onion cultivars (Crowther *et al*., 2005). TSS and soluble sugars may increase during fruit ripening due to the action of sucrose-phosphate synthase (SPS), a key enzyme in sucrose biosynthesis (Hubbard *et al*., 1991). This enzyme is activated by ethylene and the ripening process itself during storage (Langenkamper *et al.,* 1998). In onion too slight increase in TSS at the early stage of storage and then the reduction (Woldetsadik and Workneh, 2010). Due fructans are hydrolyzed to fructose during initial storage period and results in higher TSS. But dormancy period come to an end with the progress of storage while sprouting starts and sucrose is synthesized to organic acids and transported for the growth of sprout, ultimately it declines TSS content in bulbs (Pak *et al.*1995). Fructose, glucose, sucrose and fructans (degrees of polymerization 3-15) have been the only non-structural carbohydrates found in onion bulb tissues (Darbyshire and Henry, 1981) and can contribute up to 65 per cent or more of dry weight. Research to date has reported on temporal changes in carbohydrate composition in onion bulbs during development or storage (Kahane *et al*., 2001).

In the present investigation too the same trend is observed. However, treatments containing SA exhibited controlled increase in TSS. It may be due to SA effectively protects cell walls by decreasing the expression of degrading enzymes and as a consequence prevents from dramatic increase in TSS content of the cells.

The total soluble sugar were highest with chemical spray as compared to the control. The results were comparable with Ghoname (2007). Great increase in TSS was noticed treatment T_{11} (Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @

0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) (15.14^{o}B) and T_{12} (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) (14.93^{o}B) may be due to high dry matter bulbs are able to accumulate higher TSS concentrations without taking up more water because of their ability to synthesise and store highly polymerized fructans (Sinclair *et al*., 1995).

The highest TSS content in onion bulbs was mainly attributed to the maximum conversion of polysaccharides into soluble forms of sugars. It may also, due to accumulation of more carbon dioxide and low oxygen content in the bulbs and this retardation effect on respiration ultimately reduces the transpiration process, which minimises the TSS loss (Mahadevaswamy, 1984). The foliar sprays of these chemicals was effective in increasing the TSS content of onion which might be due to faster conversion of insoluble sugars into soluble forms and least utilization of organic acids. The results of present investigations are in conformity with the findings of Singh and Dhankhar (1992), Misra and Pandey (1979) and Aoyagi *et al*. (1997) in onion.

5.12 Pyruvic acid content

The consumption of onion is increasing in developed countries and developing countries every year. The compounds like sugars and organic acids are contributing to the organoleptic taste and contribute to the disctictive flavour and aroma. Pungency level and total solubule sugars are important quality attributes of onion bulbs. The contents of solubule carbohydrates contribute to onion sweetness. All the above parameters are important in processing and export quality of bulbs (Simon, 1995). Many of such compounds can be chemically quantified. Thus an attempt has been made to estimate the pungency in the present investigation and the results obtained are briefly discussed.

The characteristic flavuor and aroma of onions are developed through unstable and complicated chain reaction (Yoo, *et al*., 2012). The flavour profile of onions (*Allium cepa* L.) is mainly determined by the 3 major flavor precursors of S-alk(en)yl-L-cysteine sulfoxides (ACSOs): S-methyl-, S-propyl and S-1-propenyl cysteine sulfoxides. In general, the S-1-propenyl cysteine sulfoxides (PRENCSO) is found in the

highest concentration, whereas the S-methyl-cysteine sulfoxides (MCSO) and S-propyl-cysteine sulfoxides (PCSO) are found to have lower concentrations (Lancaster & Boland, 1990). In the process of biosynthesis of ACSOs, sulfur (S) is absorbed by the roots as sulfate (SO_4^{2-}), reduced to sulfide in the plant, and assimilated into cysteine (Randle *et al.,* 1995). Some of the cysteine go through the glutathione cycle and then incorporated into a variety of γ-glutamyl peptides (γ-GPs) which are intermediates in the pathway to ACSOs (Lancaster & Shaw, 1989).

When the onion cells are mechanically ruptured, the enzyme alinase (E. C. 4.4.1.4) is released from vacuole and hydrolyzes the flavour precursors (ACSOs). This reaction produces pyruvic acid, ammonia and many sulfur volatiles including unstable sulfenic acids (Whitaker, 1976). Sequentially, these acids rapidly react to form methyl thiosulfinates and tear-causing propanethial S-oxides, generally referred to as the lachrymatory factor (LF) (Corzo-Martínez, *et al*., 2007; Lancaster, *et al*., 1998). Methyl thiosulfinates have been reported to be responsible for the characteristic flavours related to fresh onions (Block, 1985; Block *et al.,* 1992; Freeman & Whenham, 1976). LF is formed from S-1-propenyl sulfenic acid following PRENCSO hydrolysis, with the action of LF-synthase (Block, *et al*., 1979). The LF is responsible for the mouth burn and heat when consuming onions (Kopsell *et al*., 2002).

In general, the pyruvic acid content showed decreasing trend as the storage period progressed. The average mean value lies between 8.34 µmoles/g to 6.14 µmoles/g. The average mean value of pyruvic acid content is found to be maximum in treatment T_6 (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT) (8.71 µmoles/g) followed by T_5 (Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) (8.57 µmoles/g). Combined application of the chemicals achieved more quantum of pyruvic acid as this might be due to the fungicide azoxystrobin is well known to influence several physiological processes likely through intereaction with electron transfer in plant mitochondria (Bartlett *et al.,* 2002). Improved enzyme activity and translocation of metabolites (Amin *et al.,* 2007) due application of SA. This is in agreement with the study conducted by

Bideshki *et al.* (2013) where foliar application of SA increased the allinase activity in garlic. SA is an endogenous growth regulator with phenolic nature, which participates in regulation of several physiological processes in plants (Khan *et al.,* 2003).

5.13 Total phenol content

The chemical composition of the onion is variable and depends on cultivar, ripening stage, environment and agronomic conditions (Hamilton *et al.,* 1998; Randle and Bussard, 1993; Randle and Lancaster, 2002).

Polyphenols are the natural substances in plants that are antioxidants with the potential to protect the body from some disease. Previous studies showed that the main phenolics found in onion are quercetin, gallic acid, ferulic acid and their glycosides (Singh *et al*., 2009; Perez-Gregororio *et al*., 2010). Specifically, onion has been charecterised for its flavanol quercetin and quercetin derivatives (Roldan-Marin *et al*., 2009).

In the present investigation, with advancement in storage period, phenolics content decreased gradually in all the treatments. However, relatively less decrease was observed in treatments T_6 (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid @ 2 mM followed by foliar spray of azoxystrobin @ 0.1% at 60 + 90 DAT) (13.73 mg/100g) and T_5 (Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT (13.54 mg/100g). The combined application SA and azoxystrobin resulted in achieving relatively less decrease in phenolic content. This might be due to reduced activity of poly phenol oxidase (PPO) and higher activity of PAL enzymes. PPO is responsible for oxidation of phenolic compounds to quinones and finally to brown polymers (Barman and Asrey, 2014). The greatest loss of phenolic contents was due to increased PPO enzyme activity. Similar results were obtained by Barman and Asrey (2014) in mango, Awad, (2013) in peach and (Ali *et al.*, 2014) *in* apricot. SA as a plant harmone regulates the growth and ripening process of fruits. As a signaliing molecule SA activate the antioxidant mechanism in the plants thus maintained increased level of phenolic compounds (Ali *et al*. 2014). Valero *et al.* (2011) have also reported that SA application was effective in delaying ripening process in sweet cherry and increase in antioxidant components during storage. The decrease in

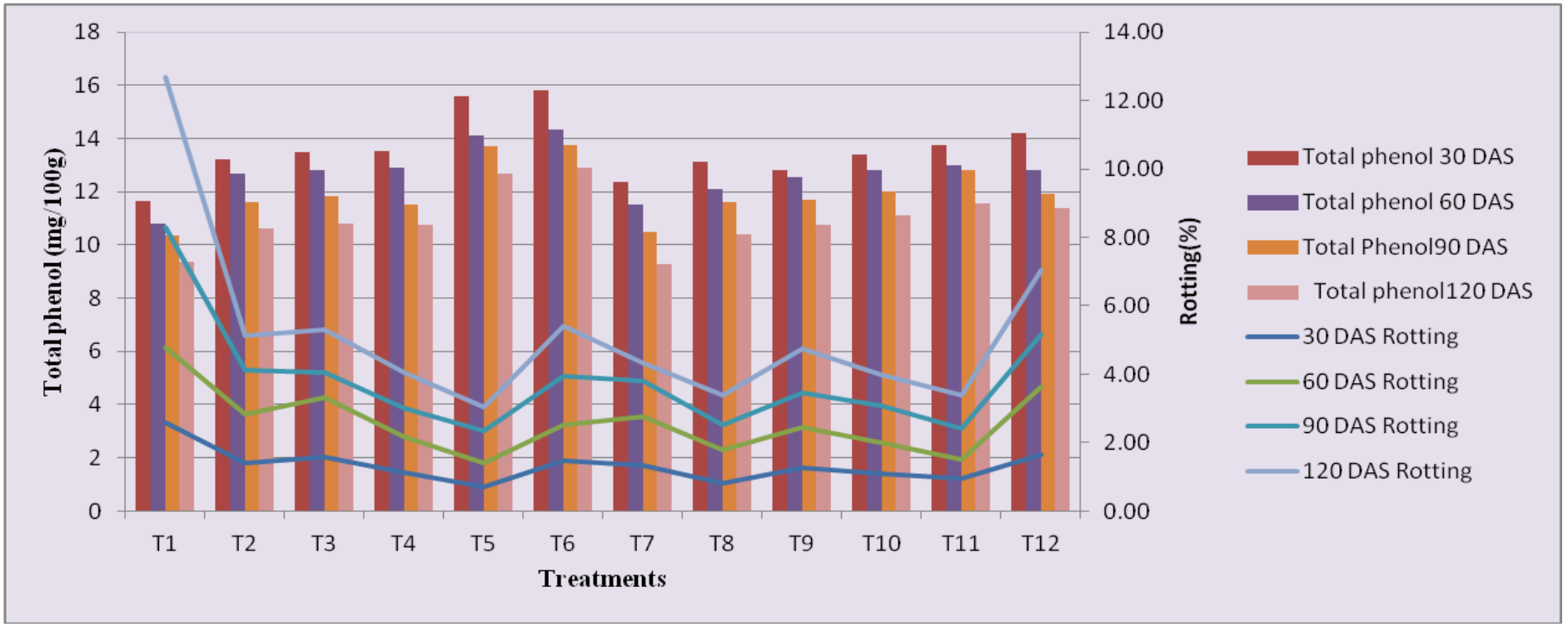

Fig. 4: Graph demonstrating relationship between total phenol content and rotting of onions during storage as influenced by field application of SA, azoxystrobin and cycocel

T_1 - Control
T_2 - Pre-harvest spray of SA (2 mM) at 60 + 90 DAT
T_3 - Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2mM) at 60 + 90 DAT
T_4- Pre-harvest spray of azoxystrobin (0.1%) at 60 + 90 DAT
T_5 - Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT
T_6 - Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT
T_7 – Pre-harvest spray of CCC 2500 ppm at 90 DAT
T_8 - Pre-harvest spray of SA (2 mM) at 60 + 90 DAT + CCC 2500 ppm at 90 DAT
T_9 - Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) at 60 + 90 DAT+ CCC 2500 ppm at 90 DAT
T_{10} – Pre-harvest spray of azoxystrobin (0.1%) + CCC 2500 ppm at 90 DAT
T_{11} - Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT + CCC 2500 ppm at 90 DAT
T_{12} - Seedling dip in SA (2 mM) + Pre-harvest spray of SA (2 mM) + azoxystrobin (0.1%) at 60 + 90 DAT + CCC 2500 ppm at 90 DAT

TPC at the later stage of storage might be due to senescence of tissues. In addition, the fungicide azoxystrobin is known to increase the activity of many enzymes. Similar results were obtained by Anand *et al*. (2008) wherein they observed azoxystrobin increasing the defence related enzymes peroxidase, phenyal alanine ammonia lyase and chitinase, defence inducing chemicals and phenolic compounds in cucumber plants. Similar results were obtained by Anand *et al.* (2008) wherein they observed azoxystrobin increased the defence related enzymes peroxidase, phenyal alanine ammonia lyase and chitinase, defence inducing chemicals and phenolic compounds in cucumber plants.

5.14 Sensory analysis

Human perception of food comes from intricate sensory system and interpretation processes. In many cases, there is a lack of information in instrumental analyses in that they rarely capture the important perceptual process, which is described as sensory experience by human brain and following response (Lawless & Heymann, 2010). Therefore, the instrumental measurements of foods have been frequently related to the consumer hedonic results to seek the critical attributes of foods or food products from consumers' perspective (Kleef, *et al.*, 2006). Sensory characteristics of quality include appearance interms of colour, texture, flavour and wholesomeness.

The onion skin colour is important which range from pale straw through to deep copper colour is acceptable for most European markets (Gorini and Testoni, 1990) and temperate countries. Cosmetic quality *i.e.* retaining an attractive apperence, is of increasing importance in competitive markets. The treatment T_8 (Pre-harvest spray of salicylic acid @ 2 mM at 60 + 90 DAT and foliar spray of cycocel 2500 ppm 90 DAT) (8.08 out of 9) and treatment T_{10} (Pre-harvest spray of azoxystrobin (0.1%) at 60 + 90 DAT and foliar spray CCC 2500 ppm 90 DAT) (7.95 out of 9). This might due to the effect of salicylic acid, azoxystrobin and cycocel in retaining the firmness, reducing the water loss and checking growth of pathogenic micro organism thus making bulbs healthier and attractive.

With respect to texture, mean maximum score was recorded by treatment T_{11} (Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) (7.88 out of 9) and T_8 (Pre-harvest

spray of salicylic acid @ 2 mM at 60 + 90 DAT and foliar spray of CCC 2500 ppm 90 DAT) (7.81 out of 9) this may be due to the effect of SA that plays a major role in maintaining the firmness of the fruits by decreasing the ethylene production in most of the crops like apple (Mo *et al.*, 2008), strawberry (Babalar *et al.*, 2007) and Kiwifruit (Aghdam *et al.*, 2009). As it reduces senescent changes, which may consequently increase the fruit shelf life.

The intensity of onion flavor can be attributed to genetic, environmental and post-harvest factors (Randle and Lancaster 2002). In the present investigation treatment T_{11} (Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) (7.79) followed by T_8 (Pre-harvest spray of salicylic acid @ 2 mM at 60 + 90 DAT and foliar spray of CCC 2500 ppm 90 DAT) (7.83 out of 9) are showing best scores for flavour and taste attributes with prolong storage of 120 days.

Overall acceptability scores reflect better quality retention during storage (Thakur *et al.*, 2012). Overall acceptability score based on bulb color, flavor, taste and texture decreased during extended storage in all treatments. Maximum acceptability scores were obtained Treatments T_{11} (Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) (7.90 out of 9) and T_8 (Pre-harvest spray of salicylic acid @ 2 mM at 60 + 90 DAT and foliar spray of CCC 2500 ppm 90 DAT) (7.81 out of 9). Similarly, minimum score was observed T_9 (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid (2 mM) at 60 + 90 DAT and foliar spray CCC 2500 ppm 90 DAT) (7.57 out of 9). Consumer acceptance of any product is determined by sensory attributes perceived by the main senses of human as color, appearance, flavor taste and texture. The sum of all sensory characters decides the overall acceptability of the product.

Initially good score obtained for color, flavor and taste, while it declined towards the end of storage as senescence proceeds. The loss in overall acceptability scores of onion bulb might be due to degradation of different parameters during storage. Loss of Color, flavor, taste and texture is due to moisture losses, the breakdown of sugars, acids and volatile compounds (Ishaq *et al*., 2009) in apricot fruit. These results are also in line with previous studies of Ishaq *et al*, (2009) and Ali *et al*. (2014) in apricot who reported a reduction in sensory score during storage of apricot fruit.

6. SUMMARY AND CONCLUSIONS

The investigation entitled with “Field application of salicylic acid, azoxystrobin and cycocel on shelf life of onion cv. Arka Kalyan” was conducted in *kharif* season of 2016-17 at College of Horticulture, Bagalkot. Chemicals response on storage behaviour, physiological, physio-chemical changes, sprouting, rotting, disease control and sensory parameters of onion bulbs (*Var.* Arka Kalyan) was evaluated in the onion bulbs packed in gunny bags and stored at ambient condition. Salient features of the investigation are summarised as below.

The imposed treatment exhibited significant differences for yield traits such as yield, number of bulbs per kg and bulb diameter. Foliar spray of salicylic acid @ 2 mM at 60 + 90 DAT followed by foliar spray of CCC 2500 ppm 90 DAT recorded highest yield, maximum number bulbs per kg and optimum bulb diameter.

In onion storage, bulbs are affected by various factors. The sprouting losses, rotting losses, physiological loss in weight, black mould are the main contributors in storage quality of onion. Minimum sprouting losses (2.26 %) were recorded in onion bulbs whose seedlings were dipped in salicylic acid @ 2 mM followed by foliar spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT which is followed by foliar spray CCC 2500 ppm at 90 DAT. Even this treatment (T_{12}) was also found promising for reducing the black mould (1.63%). Least rotting was achieved by treatments T_5 (Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT) (1.87%), T_{11} (Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) (2.07%) and T_8 (Pre-harvest spray of salicylic acid @ 2 mM at 60 + 90 DAT and foliar spray of CCC 2500 ppm 90 DAT) (2.12%). However, maximum sprouting (7.56%), rotting (7.09%) and balck mould incidence (4.18%) was noticed in treatment T_1 (control).

Combined application 2 mM salicylic acid and azoxystrobin @ 0.1% at 60 and 90 DAT followed by foliar spray of cycocel @ 2500 ppm at 90 DAT was found to be promising treatment (T_{11}) in reducing the PLW (11.62%). Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid @ 2 mM at 60 + 90 DAT (T_3) in showed

decreasing the rate of respiration (15.29 ml CO_2/kg/h). However, treatment T_1 (control) exhibited higher rate of respiration (19.34 ml CO_2/kg/h) and also maximum PLW (17.19%).

The maximum percentage of marketable bulbs was obtained in the treatment T_{11} (Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) (85.54%) followed by T_5 ((Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT) (83.52%), T_9 (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid (2 mM) at 60 + 90 DAT and foliar spray CCC 2500 ppm 90 DAT) (82.91%), T_6 (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid @ 2 mM followed by foliar spray of azoxystrobin @ 0.1% at 60 + 90 DAT) (82.36%), T_{12} (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) (82.32%), T_8 (Pre-harvest spray of salicylic acid @ 2 mM at 60 + 90 DAT and foliar spray of CCC 2500 ppm 90 DAT) (80.97%), T_4 (Pre-harvest spray of azoxystrobin @ 0.1% at 60 + 90 DAT) (80.39%) and T_3 (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid @ 2 mM at 60 + 90 DAT) (80.10%). While, minimum was seen in the treatment T_1 (Control) (70.36%).

It is important that the quality of onion bulbs is maintained during storage so that a satisfactory product can be delivered to the consumer. A range of quality measurements were done including dry weight, firmness, TSS, and pyruvic acid *etc.* Significant difference was noticed for dry matter, moisture and TSS traits of the stored onion. Least moisture content (81.60%) and maximum dry matter (18.38%) was observed in treatment T_4 (Pre-harvest spray of azoxystrobin @ 0.1% at 60 + 90 DAT).

Maximum mean TSS was observed in the treatment T_{11} (Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) (15.14 ^oB), followed by treatments T_{12} (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) (14.93 ^oB), T_{10} (Pre-harvest spray of azoxystrobin (0.1%) at 60 + 90 DAT and foliar spray CCC 2500 ppm 90 DAT) (14.91^oB), T_4 (Pre-harvest spray of azoxystrobin @ 0.1% at 60 + 90

DAT) (14.88 ^{o}B), T_7 (Pre-harvest spray of CCC 2500 ppm at 90 DAT) (14.83^{o}B), T_5 (Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT) (14.75^{o}B) and T_8 (Pre-harvest spray of salicylic acid @ 2 mM at 60 + 90 DAT and foliar spray of CCC 2500 ppm 90 DAT) (14.54^{o}B). Minimum TSS was observed in treatments T_9 (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid @ 2 mM at 60 + 90 DAT and foliar spray CCC 2500 ppm 90 DAT) (13.93^{o}B), T_2 (Pre-harvest spray of salicylic acid @ 2 mM at 60 + 90 DAT) (14.22^{o}B) and T_1 (Control) (14.23^{o}B). Maximum mean firmness was observed in the treatment T_{11} (Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) (123.98N), T_9 (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid (2 mM) at 60 + 90 DAT and foliar spray CCC 2500 ppm 90 DAT) (122.80 N), T_{12} (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) (122.72 N), T_6 (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid @ 2 mM followed by foliar spray of azoxystrobin @ 0.1% at 60 + 90 DAT) (121.84 N), T_2 (Pre-harvest spray of salicylic acid @ 2 mM at 60 + 90 DAT) (121.57 N), T_3 (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid @ 2 mM at 60 + 90 DAT) (121.29 N) and T_5 (Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT) (121.09 N) whereas, minimum mean firmness was seen in T_1 (117.45 N).

Phenols content showed a decreasing trend with the progression of the storage period. Higher mean total phenols content was noted in the treatment T_5 (Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT) (13.54 mg/100 g) followed by T_6 (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid@ 2 mM followed by foliar spray of azoxystrobin @ 0.1% at 60 + 90 DAT) (13.73 mg/100 g) while minimum in T_1 (Control) (10.09 mg/100 g). The treatments registered a decreasing trend with respect to pyruvic acid content of onion bulbs with the highest being noted in T_6 (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid @ 2 mM followed by foliar spray of azoxystrobin @ 0.1% at 60 + 90 DAT) (8.71 µmoles/gm), T_{12} (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT

followed by CCC 2500 ppm foliar spray 90 DAT) (8.31 µmoles/gm). Where as minimum quantum of pyruvic acid resulted by treatment T_1 (Control) (4.53 µmoles/gm).

The sensory characteristics (colour, texture, flavour and taste, and overall acceptability) of onion bulbs carried out with prolong storage period. The scores for overall acceptability of onion bulbs were high in the treatment T_{11} (Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) (7.90 out of 9), T_8 (Pre-harvest spray of salicylic acid @ 2 mM at 60 + 90 DAT and foliar spray of CCC 2500 ppm 90 DAT) (7.81 out of 9). While the minimum score was observed equally in T_2 (Pre-harvest spray of salicylic acid-2 mM at 90 DAT) (7.48 out of 9), T_{12} (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid @ 2 mM at 60 + 90 DAT and foliar spray CCC 2500 ppm 90 DAT) (7.57 out of 9) and T_9 (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid @ 2 mM at 60 + 90 DAT and foliar spray CCC 2500 ppm 90 DAT) (7.57 out of 9) .

Conclusions

1. Among the various treatments tried combined application of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT is the best treatment (T_{11}) , it resulted better yield traits along with reduced PLW, rotting, black mould, sprouting, marketable bulb. In addition, this treatment also express good sensory quality with respect to overall acceptability. This treatment also performs well in parameters like firmness, TSS also.

2. Combined application of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT (T_5) did well in reducing loss due to rotting and even it ranked next to treatment T_6 with respect to phenols. Treatment T_6 (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid @ 2 mM followed by foliar spray of azoxystrobin @ 0.1% at 60 + 90 DAT) showed best for total phenols and pyruvic acid.

3. Use of fungicide azoxystrobin @ 0.1% even though resulted in decreased rotting and mould incidence but the effect was relatively low in comparison with

combined use of chemicals as in treatments T_5 (Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT), T_8 (Pre-harvest spray of salicylic acid @ 2 mM at 60 + 90 DAT and foliar spray of CCC 2500 ppm 90 DAT), and T_{11}(Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT).

4. The growth retardant cycocel was found to be ineffective to control sprouting alone but it performs well with other chemicals as in treatment T_{11} (Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT) and T_{12} (Seedling dip @ 2 mM + Pre-harvest spray of salicylic acid @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray 90 DAT).

5. The chemical salicylic acid is able to reducing the respiration rate alone as in treatment T_3 (Seedling dip in salicylic acid @ 2 mM + Pre-harvest spray of salicylic acid @ 2 mM at 60 + 90 DAT). Treatments containing SA resulted in better firmness, reduced PLW, and increased pungency.

Future line of work:

1. There is need of integration of pre-harvest sprays coupled with post-harvest practices like curing, and use of scientific storage structures to get better results.

2. Larger scale trials may be undertaken with promising treatments.

3. There is need evolve combi products which reduces all the storage problems in onion *i.e.* sprouting, rotting, PLW along with enhanced yield to the farmers.

REFERENCES

Abdalla, A. A. and Mann, L. K., 1963, Bulb development in the onion (*Allium cepa* L.) and the effect of storage temperature on bulb rest. *Hilgardia*, **35**: 85-112.

Abdallah, A. A. and Mann, L. K., 2000, Bulb development in the onion (*Allium cepa* L.) and the effect of storage temperature and bulb rest. *Agric. Sci.*, **26**: 56-61.

Abeles, F. B., Morgan, P.W. and Saltveit Jr., M.E. 1992. Ethylene in Plant Biology. Academic Press, *San Diego.,* 414p.

Abrameto, M. A., Ardizzi, C. M., Gill, M. I. and Molina, L. M., 2010, Analysis of methodologies for the study of composition and biochemical carbohydrate changes in harvest and postharvest onion bulbs. *Int. J. Exptl. Bot.,* **79**: 123-32.

Adamicki, F., 2005, Effects of pre-harvest treatments and storage conditions on quality and shelf-life of onions. *Acta. Hortic*., **688**(1): 26–33.

Aghdam, M. S., Mostofi, Y., Motallebiazar, A., Ghasemneghad, M. and Fattahi, M, J., 2009. Effect of MeSA vapor treatment on the postharvest quality of Hayward kiwifruit. Paper presented at 6th *Int Post-harvest Sym.* Antalya. Turkey. 8-12 April 2009.

Agic, R., Gjorgjievska, M. C., Martinovski, G., Jevtic, S., Tevtic, S. and Lazic, B., 1997, Dynamics of losses during bulb storage from semi-arid onion cultivars. *Acta. Hortic*., **462:** 565-570.

Ahmad A, Hayat S, Fariduddin Q, Ahmad I. 2001, Photosynthetic efficiency of plants of *Brassica juncea* treated with chloro substituted auxins. *Photosynthetica*, **39**: 565–568.

Aiyer, A. K. N. (1980). Field crops of India with special refer once to Karnataka, (7thed.). Banglore, BAPPCO.

Ali, M., Farooqui, W. A. Sattar A. and Muhammed. A. (1970). Inhibition of sprouting in onions by gamma irradiations. *J. Sci. Fd. Agri. Abstr.,* 149.

Ali, S., Masud, T., Abbasi, K., Mahmood, T., and Ali, A., 2014, Biochemical attributes of apricot as influenced by salicylic acid during ambient storage. *Int. J. Biosci.* **4**(10): 176-187.

Alijo B., Abdossi, V. and Zarinnia, V., 2015, The effects of post-harvest treatments of salicylic acid and cinnamon oil on the storage of Peach. *Env. Pharmacol. Life Sci.*, **4**(4): 145-149.

Al-Obeed, R. S., 2012, Jujube post-harvest fruit quality and storagability in response to agro-chemicals pre-harvest application. *Afr. J. Agric. Res.,* **7**(36): 5099-5107.

Amin, A. A., Rashad, E. M. and EL-Abagy, H. M. H., 2007, Physiological effect of indole - 3 - butyric acid and salicylic acid on growth, yield and chemical constituents of onion plants. *J.* Appl. *Sci. Res.,* **3**(11): 1554-1563.

Anand, T., Chandrasekaran, A. I., Kuttalam, S. and Samiyappan, R. I., 2010, Evaluation of azoxystrobin (Amistar 25 SC) against early leaf blight and leaf spot diseases of tomato. *J. Agric. Technol.,* **6**(3): 469- 485.

Anand, T., Chandrashekaran, A., Kuttalam, S. P., Raguchander, T., and Samiyappan, R., 2007, Effectiveness of azoxystrobin in the control of *Erysiphe cichoracearum* and *Pseudoperonospora cubensis* on cucumber. *J. Plant Prot. Res.,* **48**(2): 147-159.

Anandhi, S. and Ramanujam, M. P., 1997, Effect of salicylic acid on black gram (*Vigna munga*) cultivars. *Indian. J. Plant Physiol.,* **2**: 178- 181.

Anbukkarasi, V., Paramaguru, P., Pugalendhi, L., Ragupathi, N. and Jeyakumar, P., 2011, Effect of pre-harvest foliar sprays of growth regulators and fungicides on growth, yield and quality of onion (*Allium cepa* L. Var. Aggregatum don). *Nat. Symp. on Alliums : Cur. Scenario and Emerging Trend*, 12-14 March 2011, DOGR, Rajgurunagar, Pune, p.214.

Anbukkarasi, V., Paramaguru, P., Pugalendhi, L., Ragupathi, N. and Jeyakumar, P., 2013, Studies on pre and post-harvest treatments for extending shelf life in onion- a review. *Agri. Reviews*, **34**(4): 256- 268.

Anke, T., Oberwinkler, F., Steglich, W. and Schramm, G., 1977, The strobilurins-new antifungal antibiotics from the basidiomycete *Strobilurus tenacellus* (Pers. ex Fr.) Sing. *J. Anti.*, **30:** 806-810.

Anonymous, (2004). *Annu. Rep,*. NHRDF, Nasik, Maharashrata.

Anonymous, (2011). Directorate of Onion and Garlic Research, Vision 2030, Rajguru Nagar, Pune.

Anonymous, 1986, *Annu. Rep., 1985-86*. Mahatma Phule Krishi Vidyapeeth, Rahuri.

Anonymous, 2003, Effect of different curing methods and period of curing on post-harvest losses in *rabi* onion. *Annu. Rep.*, NHRDF, p. 15.

Anonymous, 2012, Check list of commercial varieties of vegetables. Govt. of India, ministry of Agri. Department of Agriculture and cooperations, p. 37.

Anonymous, 2015, National horticulture database. min. of Agrico. Governament of India.

Anonymous, 2016, National horticulture database. min. of Agrico. Governament of India.

Antonio, D., María Victoria, C., Miquel, R., Jaume, F., Sebastian, M., and José, F., 2012, The effect of strobilurins on leaf gas exchange, water use efficiency and ABA content in grapevine under field conditions. *J. Plant Physiol.*, **169**(1): 379– 386.

Aoyagi, M., Makino, H. and Sato, J., 1997, The effect of storage temperature on keeping quality of onion bulbs. *Res. B. Aichiken*, **9**: 54-60.

Arreaza, M. J. and Hernandez, M. M., 2001, Evaluation of azoxystrobin on the early blight control (*Alternaria solani*) in tomatoes. *Revista de la faculated de Agronomia,* Universidad delzulia. **18**(2): 106-116.

Asghari, M. R., Hajitagilo, R. and Shirzad, H., 2007, Postharvest treatment of salicylic acid effectively controls pear fruit diseases and disorders during cold storage. In: *Proc. Int. Congr Novel approaches for the control of post-harvest diseases and disorders.* **924**: 355-360.

Asghari, M. R., Hajitagilo, R., and Jalilimarandi, R. 2009, (April 2009). Postharvest application of salicylic acid before coating with chitosan affects the pattern of quality changes in table grape during cold storage. In 6th *Int. Postharvest Sym.* Antalya, Turkey, pp. 8-12

Asthana, J. S. and Srivastava, N. S., 1978, Effect of presoaking treatment of maize seeds with salicylic acid and ascorbic acid on seedling growth and nitrogen content. *Indian J. Plant Physiol.*, **21**: 50-155.

Awad, R., 2013, Effect of post-harvest salicylic acid treatments on fruit quality of peach cv. "Flordaprince" during cold storage. *Aust J. Basic Appl. Sci.*, **7**(7): 920-927.

Babalar, M., Asghari, M., Talaei, A. and Khosroshahi, A., 2007, Effect of pre and postharvest salicylic acid treatment on ethylene production, fungal decay and overall quality of 'Selva' strawberry fruit. *Food Chem.*, **105**: 449- 453.

Bajaj, K. L., Gurdeep, K., Singh, J. and Gill, S.P.S., 1980, Chemical evaluation of some important varieties of onion. *Plant Foods Hum. Nutr.*, **30**: 117.

Bajaj, K. L., Kaur, G. and Singh, J., 1981, Lachrymatory factor and other chemical constituents of some varieties of onion. *J. Plant Foods.*, **3**(3): 199-203.

Baloch, A. F. 1994. *Vegetable crops. Horticulture.* National Book Foundation, Islamabad, Pakistan. pp. 489-537.

Barmann, K. and Asrey, R., 2014, Salicylic acid alleviates chilling injury, preserves bioactive compounds and enhances shelf life of mango fruit during cold storage. *J. Sci. Ind. res.* **73**: 713-718.

Bartlett, D. W., Clough, J. M., Godwin, J. R., Hall, A. A., Hamer, M. and Parr-Dobrzanski, 2002, B. Review: the strobilurin fungicides. *Pest Manag Sci*., **58**(1): 649–62.

Becker, W. F., Jagow, V. G., Anke, T. and Steglich, W, 1981, Strobilurin A, Strobilurin B and Myxothiazole: new inhibitors of the bc 1 segment of the respiratory chain with emethoxyacrylate system as common structural elements. *FEBS letters*, **132**: 329- 333.

Benkeblia, N. and Selselet-Attou, G. (1999a). Effects of low temperatures on changes in oligosaccharides, phenolics and peroxidase in inner bud of onion *Allium cepa* L. during break of dormancy. *Acta Agric. Sc and B Soil Plant Sci.,* **49**: 98-102.

Benkeblia, N. and Selselet-Attou, G., 1999, Effects of low temperatures on the changes in oligosaccharides, phenolics and peroxidase in inner bud of onion (Allium cepa L.) during break of dormancy. *Acta Agric. Sc and. B Soil Plant Sci.* **49**: 98–102.

Benkeblia, N. and Shiomi, N. (2004). Chilling effect on soluble sugars, respiration rate, total phenolics, peroxidase activity and dormancy of onion bulbs. *Scientia Agricola*, **61**:281-285.

Benkeblia, N., Onodera, S. and Shiomi, N. 2005, Variation in 1-fructoexohydrolase (1-FEH) and 1- kestose-hydrolysing (1-KH) activities and fructo-oligosaccharide (FOS) status in onion bulbs. Influence of temperature and storage time. *J. Sci. Food Agric*. **85**: 227–234.

Benkeblia, N., Varoquaux, P., Gouble, B. and Selselet-Attou, G. (2000). Respiratory parameters of onion bulbs (*Allium cepa*) during storage. Effects of ionizing radiation and temperature. *J. Sci. Food Agric.*, **80**: 1772-1778.

Benkeblia, N., Varoquaux, P., Shiomi, N. and Sakai, H. (2002). Storage technology of onion bulbs cv. Rouge Amposta: effects of irradiation, maleic hydrazide and carbamate isopropyl, N-phenyl (CIP) on respiration rate and carbohydrates. *Int. J. Food Sc. and Tech.,* **37**: 169-175.

Bernard, H. Z. 2004. Onions: Commercial Vegetable Recommendations. Extension Bull. pp 1307 (Revision). Web site. htm.

Bhattarai, S. P. and Subedi, P.P., 1998, Effect of curing and storage methods on postharvest losses of onion bulbs in the low hills. *Lulme Agric. Res. Cent.*, **98**: 20.

Bhonde, S. R. and J.S. Bhadauria. 1995. Effect of curing on keeping quality of small onion. News Letter. *Nat. Hort. Res. Dev. Found.*, **15(4)**: 1-4

Bhonde, S. R., K.J. Srivastava, H.K. Sharma and A.B. Chougule. 1996. Effect of water stress before harvesting on storage life of onion. News Letter. *Nat. Hort. Res. Dev. Found.*, **16**(4): 1-4.

Bhujbal, B.G. and Patil, A.V., 1978, Preliminary trial with cycocel on some varieties of tomato. *J. Res.*, **4**: 136-139.

Bideshki, A., Arvin, A. J. and Darini, M., 2013, Interactive effects of Indole-3-butyric acid (IBA) and salicylic acid (SA) on growth parameters, bulb yield and allicin contents of garlic (*Allium sativum*) under drought stress in field. *Int. J. Agron and Plant Prod.*, **4**(2): 271- 279.

Blanco, H.G. and Oliveira, D.A., 1971, The effect of foliar applied growth regulators on the storage of onion bulbs. *Arguivas do Inst Biologioc*, **38**(3): 89-94.

Block, E., 1985, The chemistry of garlic and onions. *Sci Am*, **252**: 114-119.

Block, E., 1992, The organosulphur chemistry of the genus *Allium* - implications for the organic chemistry of sulphur. *Angewandte Chemie Int. Ed. Eng.*, **31**: 1135-1178.

Block, E., 1992, The organosulphur chemistry of the genus *Allium* - implications for the organic chemistry of sulphur. *Angewandte Chemie Int Ed Eng.*, **31**: 1135-1178.

Block, E., Penn, R. E., and Revelle, L. K., 1979, Structure and origin of the onion lachrymatory factor. A microwave study. *J Am Chem Soc*, **101:** 2200-2201.

Bonasia, A., Conversa, G., Lazzizera, C. and Elia, A., 2013, Pre-harvest nitrogen and Azoxystrobin application enhances postharvest shelf-life in Butter head lettuce. *Postharvest Biol. Technol.*, **85**: 67- 76.

Bonasia, A., Conversa, G., Lazzizera, C. and Elia, A., 2013, Pre-harvest nitrogen and Azoxystrobin application enhances postharvest shelf-life in Butter head lettuce. *Postharvest Biol. Technol.*, **85**: 67- 76.

Bottner, H., 1970, Importance of ventilation during the post-harvest storage of onion. *Dtsone Gartenb*, **17**: 245-247.

Brewster, J. L., 1977a, The physiology of the onion. Part 2. *Hort. Abstr.*, **47:** 103-112.

Brewster, J. L., 1990, Physiology of crop growth and bulbing. In: *rabi*nowitch, H. D. and Brewster, J. L. (Eds.) *Onions and Allied Crops. Volume1*. *Botany, Physiology and Genetics*, CRC Press, Florida.

Brewster, J. L., 1977, The physiology of the onion. *Hortic Abstr.*, **47**: 103- 112.

Brewster, J. L., 1987, The effect of temperature on the rate of sprout growth and development within stored onion bulbs. *Ann. Appl. Bio.*, **111**: 463- 467.

Brice, J. R., Bisbrown, A. J. K. and Curd, L., 1995, Onion storage trials at high ambient temperature in the Republic of Yemen. *J. Agric Engi Res.*, **62**: 185-192.

Brien, R. M., Chamberlain, E. E., Dye, D.W., Harrison, R. A., and Smith, H. C., 1959, Diseases and pests of onions in New Zealand. DSIR, Auckland, New Zealand. 24 p.

Briggs, W. H. and Goldman, I. L., 2002, Variation in economically and ecologically important traits in onion plant organs during reproductive development. *Plant Cell Environ*, **25**:1031-1037.

Campbell, W. H., 2002. Molecular control of nitrate reductase and other enzymes involved in nitrate assimilation. In: Foyer, C.H., Noctor, G. (Eds.),

Photosynthetic Nitrogen Assimilation and Associated Carbon and Respiratory Metabolism.

Carter, C. E., Partis, M. D. and Thomas, B., 1999, The expression of histone 2A in onion (*Allium cepa*) during the onset of dormancy, storage and emergence from dormancy. *New Phytol*. **143**: 461–470.

Chandra, A. and Bhatt, R. K., 1998, Biochemical and physiological response to salicylic acid in relation to the systemic acquired resistance. *Photosynthetica*, **35**: 255–258.

Chandrababu, R., Manian, K., Nagarajan, M. and Ramachandran, T. K., 1995, Effect of mepiquat chloride on growth and yield of groundnut. *Madras Agril. J.*, **82** (3): 229-230.

Chang, W. N., Chang, Y. H., Su, A.Y. and Kuo, F.Y., 1987, Studies on onion storage. *ASPAC Book Series*, **36**: 166-176.

Chaobasingh, U. and Bhattacharjee, S. K., 1998, Effect of pre-harvest treatments of SADH, cycocel and ethrel on post-harvest life of Rakta gandha roses. *Indian J. Plant Physiol.*, **3** (1):65-67.

Chauhan, K. P. S., Singh, S. P. and Chougule. A. B., 1995. Studies on the effect of windrow curing, neck cut and shade curing on export quality of onion bulbs during storage. *News Letter Nat Hort. Res. Dev. Found.*, **15**(4): 5-7.

Chetti, M. B., 1991, Evaluations of chamatkar on groundnut. *Pestol.*, **15**(8): 43-50.

Chope, G. A., Cools, K., Hammond, J. P., Thompson, A. J. and Terry, L. A., 2012, Physiological, biochemical and transcriptional analysis of onion bulbs during storage. *Ann. Bot.*, **109**: 819–831.

Chope, G. A., Terry, L. and White, P., 2006, Effect of controlled atmosphere climates. In: H. D. *rabi*nowitch and J. L. Brewster (eds), pp. 31-48.

Chope, G. A., Terry, L. and White, P., 2007., The effect of the transition between controlled atmosphere and regular atmosphere storage on bulbs of onion cultivars SS1, Carlos and Renate. *Biol. Technol*, **44**: 228- 239.

Chope, G., 2006, Understanding the mechanisms behind onion bulb dormancy in relation to the potential for improved onion storage. *Ph. D. Thesis*, Cranfield university, Plant Science Laboratory.

Chopra, A., 2010, Understanding onion storage-issues and solutions for India. *www.onions-potatos.com/* storage.

Corzo-Martínez, M., Corzo, N., and Villamiel, M. (2007). Biological properties of onions and garlic. *Trends in Food Sci. Technol.*, **18**(12): 609-625.

Crowther, T., Collin, H. A., Smith, B., Tomsett, A. B., O'Connor, D. and Jones, M. G., 2005, Assessment of the flavour of fresh uncooked onions by taste panels and analysis of flavour precursors, pyruvate and sugars. *J. Sci. Food Agri.*, **85**: 112- 120.

Darbyshire, B. and Henry, R. J., 1979, The association of fructans with high percentage dry weight in onion cultivars suitable for dehydrating. *J. Sci. Food Agri.*, **30**: 1035- 1038.

Darbyshire, B. and Henry, R.J., 1981, Difference in fructose content and synthesis in some *Allium cepa. New Phytol.*, **87**(2): 249-256.

Darbyshire, B., 1978, Change in the carbohydrate content of onion bulbs stored for various times at different temperature. *J. Hortic. Sci.*, **53**(3): 195-201.

Das, A. K., Sadhu, M. K. and Som, M. G., 1980, Effect of foliar application of NAA, CCC and ethrel on growth and yield of garlic. *Indian Cocoa Arecanut and Spices J.*, **20**(2): 57-61.

Denancé, N., Sánchez-Vallet, A., Goffner, D., and Molina, A., 2013, Disease resistance or growth: the role of plant hormones in balancing immune responses and fitness costs. *Front Plant Sci.*, **4**:1–12.

Diedhiou, P. M., Mbaye, N., Rokhaya, F. and Samb, P. I., 2014, Field tests of fungicides against post harvest rot of mangoes in Senegal. *Int. J. Sci. Env. Technol.,* **3**(2): 597- 606.

Dingley, J. M. 1969, Records of plant diseases in New Zealand. DSIR, Auckland, New Zealand. p. 298.

Doug, W., 2004. Food and Rural Revitalization. *Plant Sci. Department University of Saskatchewan,* Canada. Onions Production in Saskatchewan.htm.

Durrant, W. E., and Dong, X., 2004, Systemic acquired resistance. *Ann. Rev. Phyto. Pathol*, **42**: 185-209.

Eckert, J.W. 1979, Pathological diseases of fresh fruits and vegetables. *J. Food Biochem*. **2**: 243-249.

Eckert, J.W. 1988. The chemical control of post harvest disease: Deciduous fruits, berries, vegetables, root and bulb crops. *Ann. Rev. Phyto. Pathol*. **26**: 433-469.

El-Monem, E. A. A., Zahran, A. A. and Shaban, A. E., 2013, Role of some post-harvest treatments in maintaining mango fruit quality during cold storage. *J. Applied Sci. Res.,* **9**(3): 2355-2366.

El-Nagerabi, S.A.F.; Ahmed, A.H.M. 2001: The effect of black mould (*Aspergillus niger*) on two Sudanese cultivars of cotton. *Trop. Sci.* **41:** 95-99.

El-Wahed, A. M. Amin, S. A., Rashed, A. A., and El-Sh, M., 2006, Physiological effect of some bioregulators on vegetative growth, yield and chemical constituents of yellow maize plants. *World J. of Agric. Sci.,* **2**(2): 149-155.

Ernst, M. K., Bufler, G., Röske, M., Ritzkowski, M., Metzger, C. and Liebig, H. P. (1999). Cultivar and temperature effects on starch in the primary thickening meristem of onion bulbs. *J. Hortic. Sci. Biotechnol.,* **74:** 588-593.

Ernst, M. K., Chatterton, N. J., Harrison, P. A. and Matitschka, G. (1998). Characterization of fructan oligomers from species of the genus *Allium* L. *J. Plant Physiol.,* **153**: 53-60.

Ernst, M. K., Praeger, U. and Weichmann, J. (2003). Effect of low oxygen storage on carbohydrate changes in onion (*Allium cepa* var. *cepa*) bulbs. *Eur. J. Hortic. Sci.,* **68**: 59-6

Espen, L., Morgutti, S., Abruzzese, A., Negrini, N., Rivetta, A., Quattrini, M., Cocucci M., and Cocucci, S. M. 1999, Changes in the potato (*Solanum tuberosum* L.) tuber at the onset of dormancy and during storage at 23°C and 3°C. I. Biochemical and physiological parameters. *Potato Res*., **42**: 189–201.

Fariduddin, Q., Hayat, S. and Ahmad, A., 2003, Salicylic acid influences net photosynthetic rate, carboxylation efficiency, nitrate reductase activity and seed yield in *Brassica juncea*. *Photosynthetica.,* **41**: 281- 284.

Fenwick, G. R. and Hanley, A. B. (1985). The genus *Allium* - Part 1. *CRC Crit Rev Food Sci Nutr.,* **22**: 199-271.

Freddo, A. R., Cechin, *F. E. And* Mazaro, S. M., 2013, Conservation of post-harvest leaves of green onion (*Allium fistulosum* L.) with the use of salicylic acid solution. *Brazilian J. Appl. Technol. Agri. Sci.,* **6**(3): 87- 93.

Freeman, G. G., and Whenham, R. J., 1976, Thiopropanal S-oxide, alk(en)yl thiosulphinates and thiosulphonates: Simulation of flavor components of *Allium* species. *Phtochem.,* **15**: 187-190.

Fustos, Z. S., Burba, J. L. and Galmarini, C. R., 1997, The role of the dry scale in the dormancy of onions (*Allium cepa* L.). *Acta. Hort.,* **433**: 445-446.

Gasti, V. D., Madalageri, M. B., Chakravorty, S. and Mulge. R., 2011a, Response of nutrient uptake by garlic as influenced by integrated nutrient management. *Nat. Symp. on Alliums : Cur. Scenario and Emerging Trend,* 12-14 March 2011, DOGR, Rajgurunagar, Pune, p. 195.

Gasti, V. D., Madalageri, M. B., Chakravorty, S. and Mulge. R., 2011b, Garlic production as influenced by growth retardants. *Nat. Symp. on Alliums : Cur. Scenario and Emerging Trend,* 12-14 March 2011, DOGR, Rajgurunagar, Pune, p. 194.

Gasti, V. D., Madalageri, M. B., Chakravorty, S. and Mulge. R., 2011c, Effect of growth retardants in onion. *Nat. Symp. on Alliums : Cur. Scenario and Emerging Trend,* 12-14 March 2011, DOGR, Rajgurunagar, Pune, p. 195. Gallina, P. M., Giovanni, C., Alessandro, M. and Alessandro, N., 2012, Changes in the pyruvic acid content correlates with phenotype traits in onion clones. *Aust. J. Crop Sci.,* **6**(1): 36-40.

Gautam, N. Kumar, D. Kumar, D. Kumar, S. Sharma, S. and Dogra, B., 2014, Growth and yield of garlic (*Allium sativum* L) as influenced by clove weight and plant growth regulators. *Int. J. Farm Sci.,* **4**(3): 49-57.

Ghoname, A., Fawzy, Z. F., Bassiony, A. M., Raidand, G. S. and Baky, M. M. H. A., 2007, Reducing onion bulbs flaking and increasing bulb yield and quality by potassium and calcium application. *Aust. J. Basic. Appl. Sci.,* **1**(4): 610-618.

Gimenez-Ibanez S, Solano R (2013). Nuclear jasmonate and salicylate signaling and cross talk in defense against pathogens. *Front Plant Sci.,* **4**: 72.

Glaab, J. and Kaiser, W.M., 1999. Increased nitrate reductase activity in leaf tissues after application of the fungicide Kresoxim-methyl. *Planta* **207**: 442–448.

Goburdhan, S., 1980, Aspects of warm temperature storage of onion. *Hortic Abstr.*, **24**: 6.

Gopalakrishnan, T. R., 2010, Horticulture Science Series 4. Ed. Peter, K. V., New India publishing Agency, New Delhi, p. 226.

Gorini and Testoni, 1990, Onion skin colour and kepping quality. Annual Report for 1965. National Vegetable Research Station, Wellesbourne, UK, p. 47-49.

Grewal, H. S., Kolar, J. S., Cheema, S. S. and Sing, G. 1993, Studies on the use of growth regulators in relation to nitrogen for enhancing sink capacity and yield of ghobhi sarson (*Brassica napus*). *Ind. J. Plant Physiol*., **36:** 1-4.

Griffiths, G., Trueman, L., Crowther, T., Thomas, B. and Smith, B., 2002, Onions – A global benefit to health. *Phytotherapy Res.,* **16**: 603-615.

Grubben, J. H. and Denton, D. A. 2004. *Plant Resources of Tropical Africa*. Prota Foundation, Wageningen; Backhuys, Leiden, CTA, Netherlands.

Gubb, I. R. and MacTavish, H. S., 2002, Onion pre- and postharvest considerations. In: *rabi*nowitch HD, Currah L, eds. *Allium crop science*: recent advances. Wallingford: CABI Publishing, 233–265.

Habba, E. E., 2003, Physiological studies of some growth regulators on the growth, yield and chemical constituents of onion plants (*Allium cepa* L.). *J. Agric. Sci. Mansoura Univ.,* **28**(3): 1645- 1653.

Hadokoa, N. L. and Ito, M. N., 1968, Some biological changes in vegetable during storage. *Hortic. Abstr.,* **11**: 764.

Hamasaki, R. Valenzuela, H. and Shimabuku, R. 1999. *Bulb Onion Production in Hawaii*, College of Tropical Agriculture and Human Resources (CTAHR), Hawaii, USA.

Hamilton, B. K., Yoo, K. S., and Pike, L. M., 1998, Changes in pungency of onions by soil type, sulphur nutrition and bulb maturity. *Sci Hortic*., **74**: 249–256.

Hansen, S. L. and Henriksen, K., 2001, Increasing the Dry Matter Production in Bulb Onions (*Allium cepa* L.). *Denmark Department Fruit, Vegetable Food Sci*., **2:** 147-152.

Harrison, S. and Tedford, E., 2002, Quadris: A novel fungicide for disease control in rice (In: proceeding of the temperate rice conference). *B. Irri. India.,* pp. 289-294.

Hassan, M. H. A. 1996. Effect of irrigation management and stage of maturity on predisposition and bulb yield to storage diseases. *Assiut. J. Agric. Sci.,* **27**(3): 169-180.

Havey, M. J. and Randle, W. M., 1996, Combining abilities for yield and bulb quality among long- and intermediate-day open-pollinated onion populations. *J. Am. Soc. Hortic. Sci.*, **121**: 604-608.

Havey, M. J., 1999, Advances in new *Alliums*. In: Janick, J. (Ed.) *Perspectives on New Crops and New Uses*, ASHS Press, Alexandria, Virginia.

Hemberg, T. 1967, The action of endogenous growth-inhibiting substances and gibberellins on the rest period of the potato tuber. Wiss. Zeitschr. Univ. Rostock **16**: 661–666.

Herold, B., Oberbarnscheidt, B. and Geyer, M., 1998, Mechanical load and its effect on bulb onions due to harvest and post-harvest handling. *J.Agric Eng Res.*, **71**: 373-383.

Hewitt, H., G., 1998, Strobilurins. Fungicides in Crop Protection. *CAB Intrnational New* York, pp.128- 129.

Hole, C. C., Drew, R. L. K. and Gray, D., 2000, Humidity and the mechanical properties of onion skins. *Postharvest. Biol. Technol.*, **19**: 229-237.

Hooper, L. and Cassidy, A., 2006, A review of the health care potential of bioactive compounds. *J. Sci. Food Agr*. **86**: 1805-1813.

Hubbard, N. L., Pharr, D. M., and Huber, S. C., 1991, Sucrose phosphate synthase and other sucrose metabolizing enzymes in fruits of various species. *Plant Physiol*. **82**: 191-196.

Hurst, W. C., Shewfelt, R. L. and Schuler, G. A., 1985, Shelf-life and quality changes in summer storage onions (*Allium cepa*). *J. Food Sci.*, **50**: 761-763.

Ibarra, M. D., Maiti, R. and De-leon, B., 1994, Effect of gibberellic acid and 2.4-D on the Cultivation yield of garlic (*Allium sativum* L.). *Phyton* (Buenos Aires), **56**(O): 91-94.

Imai, S., Tsuge, N., Tomotake, M., Nagatome, Y., Sawada, H., Nagata, T. and Kumagai, H. (2002). Plant biochemistry: An onion enzyme that makes the eyes water. *Nature*, **419**: 685.

Ishaq, S., Rathore, H. A., Masud, T., Ali, S., 2009, Influence of post harvest calcium chloride application, ethylene absorbent and modified atmosphere on quality characteristics and shelf life of apricot (*Prunus armeniaca* L.) fruit during Storage. *Pak. J. Nutr*. **8**(6): 861-865.

Jaime, L., Martin-Cabrejas, M. A., Molla, E., Lopez-Andreu, F J. and Esteban, R. M. (2001). Effect of storage on fructan and fructooligosaccharide of onion (*Allium cepa* L.). *J. Agric. Food Chem.,* **49**: 982-988.

Jangam, A. K. and Thali, P, 2010, ICAR Research Complex for Goa, Ela, Old Goa, Goa (India), 403-402.

Javaheri, M., Mashayekhi, K., Dadkhah, A. and Tavallaee, F. Z., 2012, Effects of salicylic acid on yield and quality characters of tomato fruit (*Lycopersicum esculentum.* Mill). *Int. J. Agric. Crop Sci.,* **4**(16): 1184- 1187.

Jayakumar, P. and Thangaraj, M., 1996, Physiological and biochemical effects of mepiquat chloride in groundnut (*Arachis hypogaea*). *Madras Agril. J.,* **85**: 23-26.

Jones, H. A. and Mann, L. K. (1963). Onions and their allies, botany, cultivations and utilization. Leonard Hill, London.

Jones, H. A. Preliminary report on onion dormancy studies. *Proc. Am. Soc. Hortic. Sci.* 1920, **17**: 128–133.

Jones, M. G., Hughes, J., Tregova, A., Milne, J., Tomsett, A. B. and Colin, H. A. (2004). Biosynthesis of the flavour precursors of onion and garlic. *J. Exp. Bot,*, **55**: 1903-1918.

Joshi, B. L. and Bhushan, C. P., 2002, Post-harvest handling of horticultural produces. CBS publishers and distributors, New Delhi.

Kahane, R., Delaserve, B. T. and Rancillac, M., 1992, Bulbing in long-day onion (*Allium cepa* L) cultured *in vitro* - comparison between sugar feeding and light induction. *Annuals Bot.,* **69**: 551-555.

Kahane, R., Vialle-Guerin, E., Boukema, I., Tzanoudakis, D., Bellamy, C., Chamaux, C. and Kik, C., 2001, Changes in non-structural carbohydrate composition during bulbing in sweet and high-solid onions in field experiments. *Env. Exp. Bot.,* **45**: 73-83.

Kale, P.N., Warade, S.D. and Jagtap, K.B., 1992, A decade of research on storage of onion under ambient conditions. *Maharashtra J. Hort.,* **6**(1): 68-72.

Kallolkumar, P., Narendra, S. and Netrapal, 1999, Physiological effect on growth, yield and storage qualities of onion (*Allium cepa* L.). *Indian J. Agric. Sci.*, **69**(2): 126-128.

Kamal, M., Takahashi, H., Mikoshiba, H., Ota, Y., 1995, Analysis of soybean Yield components as affected by plant growth regulators applied at flowering stages. *Jpn. J. Trop. Agric.*, **39**(3): 184-189.

Kazemi, M., Aran, M. and Zamani, S., 2011, Effect of salicylic acid treatments on quality charecterstics of apple fruits during storage. *American J. plant physiol.,* **6**(2): 113.119.

Kepkawa, A., 1966, The influence of time and rate of application on the effectiveness of maleic hydrazide in the storage of onions under different conditions. *Roczn Nank Rol Ser.*, **91**: 363-381.

Ketter, C. A. and Randle, W. M., 1998, Pungency assessment in onions. Proceeding of the 19th Workshop and Conference of the Association for Biology Laboratory Education (ABLE). 177-196.

Khademi, Z. and Ershadi, A., 2013, Postharvest application of salicylic acid improves storability of peach (*Prunus persica cv*. Elberta) Fruits. *Int. J. Agri. Crop Sci*., **5**(6): 651-655.

Khan, W., Prithiviraj, B. and Smith, D. L., 2003, Photosynthetic response of corn and soybean to foliar application of salicylates. *J. Plant Physiol.,* **160**: 485- 182.

Kleef, E., van Trijp, H. C. and Luning, P., 2006, Internal versus external preference analysis: An exploratory study on end-user evaluation. *Food Qual. Pref.,* **17**(5): 387-399.

Ko, S-K., Chany, W-N., Wang, J-F., Cherng, S-J. and Shanmugasundaram, S. (2002). Storage variability among short-day onion cultivars under high temperature and high relative humidity, and its relationship with disease incidence and bulb characteristics. *J. Am. Soc. Hort. Sci.,* **127**: 848-854.

Kodic, B., 1971, Comparative cold storage trial of onions exposed to the air. *Hort. Abstr.,* **41**(1): 173.

Komochi S. 1990. Bulb dormancy and storage physiology. In: *rabi*nowitch HD, Brewster JL, eds. Onions and allied crops, Vol.1. Boca Raton, FL: CRC Press, **89**–111.

Kopsell, D. E. and Randle, W. M., 1997, Short-day onion cultivars differ in bulb selenium and sulphur accumulation which can affect bulb pungency. *Euphytica,* **96**: 385-390.

Kopsell, D. E., Randle, W. M. and Eiteman, M. A., 1999, Changes in the S-alk(en)yl cysteine sulfoxides and their biosynthetic intermediates during onion storage. *J. Am. Soc. Hort. Sci.,* **124**: 177-183.

Kopsell, D. E., Randle, W. M., Schmidt, N. E. (2002). Incubation time, cultivar, and storage duration affect onion lachrymatory factor quantification. *Hort. Sci.*, **37**(3): 567-570.

Kord, M. and Hathout, T., 1992, Changes in some growth criteria, metabolic activities and endogenous hormones in tomato plants consequent to spraying with different concentration of salicylic acid. *Egypt. J. physiol. Sci.*, **16**: 117.

Krawiec, M. 2002. Evaluation of storage losses of onion sets depending on the storage temperature. *Folia Hortic.*, **14**(1):13-20.

Krishna, H. Das, B. Attri, B. Kumar, A. and Ahmed, N., 2012, Interaction between different pre- and post-harvest treatments on shelf life extension of 'Oregon Spur' apple. *Fruits*, **67**: 31–40.

Kukanoor, L., 2005, Post – harvest studies in onion Cv. N-53. *Ph.D. (Hort.) Thesis, Univ. Agric. Sci., Dharwad.*

Kumara, B. R. and Patil, S., 2015, Effect of pre-harvest sprays of growth regulators and chemicals on storage life of garlic (*Allium sativum L.*). *J. Spi. Aroma. Crops*, **24**(1): 47–50.

Lam, P. F. S., Kosiyachinda, M. C. C., Lizada, D. B. J., Mendoza, S., Prahawati and Lee, S., K., 1987, Postharvest physiology and storage of rambutan. *Asian food handling bureau*, Kuala Lumpur, pp. 37–50.

Lancaster, J. E., and Boland, M. J., 1990, Flavor biochemistry. In H. D. *rabi*nowitch, and J. L. Brewster (Eds.). *Onions and allied crops* **3**: 33-72 Boca Raton, FL: CRC Press.

Lancaster, J. E., and Shaw, M. L., 1989, γ-Glutamyl peptides in the biosynthesis of S-alk (en) yl-L-cysteine sulphoxides (flavor precursors) in *Allium*. *Phytochemistry*, **28:** 455-460.

Lancaster, J. E., Shaw, M. L. and Randle, W. M., 1998, Differential hydrolysis of alk(en)yl cysteine sulphoxides by alliinase in onion macerates: flavour implications. *J. Sci. Food Agri.*, **78**: 367-372.

Lancaster, J. E., Triggs, C. M., De Ruiter, J. M. and Gandar, P. W., 1996, Bulbing in onions: Photoperiod and temperature requirements and prediction of bulb size and maturity. *Annals Bot.*, **78**: 423-430.

Lang, G.Y., Early, J. D., Martin, G. C. and Darnell, R. L. 1987, Endo, para, and ecodormancy: Physiological terminology and classification for dormancy research. *Hort. Sci.*, **22**: 371–377.

Langenkamper, G., McHale, R., Gardner, R. C., and MacRae, E. (1998). Sucrose phosphate synthase steady-state mRNA increases in ripening kiwifruit. *Plant Mol. Biol*., **36**: 857-869.

Lawless, H. T., and Heymann, H., 2010, Sensory evaluation of food: Principles and practices (2nd ed.). New York, NY: Springer Science and Business Media.

Lazić, B., Đurovka, M. and Gvozdenović, J., 2000, Uticaj ekoloških uslova i agrotehničkih mera na prinos i kvalitet crnog luka. Zbornik radova Instituta za ratarstvo i povrtarstvo. Sv. **33**: 135- 144.

Lisińska, G., Leszczyński, W., 1989, Potato Science and Technology. *Elsevier Elsevier Appl Sci.*, London, New York.

Liu, C., Guo, J., Cui, Y., Lü, T., Zhang, X., and Shi, G., 2011, Effects of cadmium and salicylic acid on growth spectralreflectance and photosynthesis of castor bean seedlings. *Plant Soil.*, **344**: 131–141.

Lolaei, A., Kaviani, B., Rezaei M., Raad, M., and Mohammadipour, R. 2012, Effect of pre- and postharvest treatment of salicylic acid on ripening of fruit and overall quality of strawberry (*Fragaria ananasa* Duch cv. Camarosa) fruit. *Annals Biol. Res.*, **3**(10): 4680-4684

Lu, X. H., Sun, D. Q., Mo, Y. W., Xi, G. J. and Sun, G. M., 2010, Effects of post-harvest salicylic acid treatment on fruit quality and anti-oxidant metabolism in pineapple during cold storage. *J. Hort. Sci. Biotechnol.*, **85**(5): 454-458.

Mahadevaswamy, K. L., 1984, Studies on the simple storage techniques for onion cv. Ballary red with pre-harvest treatment of maleic hydrazide. *M.Sc. Thesis*, UAS, Bangalore.

Maiti, S. C., Basu, R. N. and Sen, P. K., 1972, Chemical control of growth and flowering in mango (*Mangifera indica* L.). *Acta Hort*., **24**: 192-195.

Matejko, C. and Dablbelm, H., 1991, Polyamine synthesis and its relation to dormancy in *Allium cepa* L. *Biochem. Physiol* **187**:217–226.

Mateo, A., Mu¨ hlenbock, P., Rusterucci, C., Chang, C. C., Miszalski, Z., Karpinska, B., Parker, J. E., Mullineaux, P. M. and Karpisnki, S. 2004. Lesion simulating disease1 is required for acclimation to conditions that promote excess excitation energy. *Plant Physiol.*, **136**: 2818–2830.

Mathur, M. M., 1971, Responses of *Allium cepa* Line transplants to different plant growth regulators. *Indian J. Hort.*, **28**(4): 296-300.

Maude, R. B., Taylor, J. D., Munasinge, H. L., Bambridge, J. M. and Spencer, A. 1984, Storage rots of onions. *Nat. Veg. Research Station, Annual Report* 1984. Welles bourne, Warwick. p. 64-66.

Melotto, M., Underwood, W., Koczan, J., Nomura, K. and He, S. Y.. 2006. Plant stomata function in innate immunity against bacterial invasion. *Cell,* **126**: 969–980.

Memane, P. G., Tomar, R. S., Kakade, D. K., Kulkarni, G. U. and Chouatia, R. S., 2008, Effect of clove weight and plant growth regulators on growth and yield of garlic (*Allium sativum* L.) cv. GG-3. *Asian J. Hort.*, **3**(1): 82-86.

Miedema, P. and Kamminga, G.C. 1994. Bulb dormancy in onion. II. The role of cytokinin in high-temperature imposed sprout inhibition. *J. Hort. Sci.* **69**: 41-45.

Miedema, P., 1994a, Bulb dormancy in onion. I. The effects of temperature and cultivar on sprouting and rooting. *J. Hort. Sci.*, **69**: 29-39.

Miedema, P., 1994b, Bulb dormancy in onion. III. The influence of the root system, cytokinin and wounding on sprout emergence. *J. Hort. Sci.,* **69**: 47-52.

Mishra, R. S. and Pande, S. C., 1979, Biochemical changes in onion bulbs during storage. *Punjab Hortic. J.*, **19**: 86-88.

Mo, Y., Gong, D., Liang, G., Han, R., Xie, J. and Li, W., 2008, Enhanced preservation effects of sugar apple fruits by salicylic acid treatment during post-harvest storage. *J. Sci. Food Agric.*, **88**(15): 2693- 2699.

Mohammadreza, A. and Morteza, S. A., 2010, Impact of salicylic acid on post-harvest physiology of horticultural crops. *Trends in Food Sci. Tech.,* **21**: 502-509.

Moharekar, S. T., Lokhande, S. D., Hara, T., Tanaka, R., Tanaka, A. and Chavan, P. D., 2003. Effects of salicylic acid on chlorophyll and carotenoid contents on wheat and moong seedlings. *Photosynthetica,* **41**: 315–317.

Nabi, G., Rab, A., Sajid, M., Farhatullah, Abbas, S. J. and Ali, I., 2013, Influence of curing methods and storage condition on the post- harvest quality of onion bulbs. *Pak. J. Bot.,* **45**(2): 455-460.

Nandasana, J. N., Patel, N. C. and Akbari, S. H., 1998, Post harvest technology of onion in Gugrat. *Natl. Hort. Res. Dev. Found*., **18**(3): 1-12.

Negi, S. and Prasad, P., 2001, Effect of salicylic acid on enzymes of nitrogen metabolism during germination of soybean. *Indian J. Plant Physiol.,* **2**: 178-181.

Nettles, V.F. and Smith, H.A., 1971, Harvesting methods and their effect on dry matter content and keeping quality of onions. *Proceeding of the Tropical Region*. *Am. Soc. Hort. Sci.*, **15**: 126-131.

Nirmal, S. V., Deore, B. P. and Patil, R. C., 1994, Effect of growth substances on yield and yield contributing traits in onion. *J. Maharashtra Agril. Univ.*, **19**(1): 136-137.

Noor, B., Izhar, A. and Mati, U.R., 1998, Post-harvest application of salicylic acid to onion bulbs for sprout inhibition. *Sarhad J. Agri.* **14**(6): 541-547.

O'Donoghue, E. M., Somerfield, S. D., Shaw, M., Bendall, M., Hedderly, D., Eason, J. and Sims, I., 2004, Evaluation of carbohydrates in Pukekohe Longkeeper and Grano cultivars of *Allium cepa*. *J. Agric. Food Chem.,* **52**: 5383-5390.

Obeng-Ofori, D., Danquar, E.Y., Ofosu-Anim, J., 2007, Vegetable and Spice Crop Production in West Africa, The City Publishers Limited, Ghana. Pp 77-79.

O'Connor, D., 1979, *Onion Storage*. Grower Books, London.

Ogata, K., 1961, Physiological studies on the storage of onion bulb. *The Uni. of Osaka Prefecture: Series B: Agri. Biol.*, B **11**: 99-120.

Pak, C., Van der plas, L. H. W. and de Boer, A. D, 1995, Respiration and ethylene evolution of certain fruits and vegetables in response to carbon dioxide in controlled atmosphere storage. *J. Food Sci. Technol.,* **30**: 29- 32.

Pak, C., Van der plas, L.H.W. and de Boer, A. D., 1995, Respiration and ethylene evolution of certain fruits and vegetables in response to carbon dioxide in controlled atmosphere storage. *J. Food Sci. Technol.,* **30**: 29-32.

Pancheva, T. V., Popova, L. P. and Uzunova, A. N., 1996, Effects of salicylic acid on growth and photosynthesis in barley plants. *J. Plant Physiol.*, **149**: 57–63.

Pandey, U. B., Bhonde, S. R. and Mishra, V. K., 1992, Shelf-life of *kharif* onion as influenced by curing and storage with foliage. *Associated Agric. Dev. Found.*, Newsletter, **13**(1): 5-8.

Pandey, U. B., S. R. Bhonde and V. K. Mishra, 1993, Shelf life of *kharif* onion as influenced by curing and storage with foliage., *AADF News Letter*, **13**(1): 5.

Pandey, U. B., Singh, L. Singh, S. P. Mishra, P. K. and L. Singh, 1992a, Studies on the effect of curing on storage life of *Kharif* onion (*Allium cepa* L.). *Associated Agric. Dev. Found.*, Newsletter, **12**(3):14-16.

Park, S.W., Kaimoyo, E., Kumar, D., Mosher, S., and Klessig, D. F., 2007, Methyl salicylate is a critical mobile signal for plant systemic acquired resistance. *Sci.*, **318**: 113-116.

Patil, J. D. and Kale, P. N., 1998, Storage studies in onion. *J Maharashtra Agri, Univ.*, **12**: 114-115.

Patil, R. S. and Kale, P. N., 1989, Screening of onion cultivars for storage quality. *Veg. Sci.*, **16**(1): 56-61.

Patil, S. B., 1994, Effect of population levels and growth retardants on growth, yield and yield attributes and quality of soybean. *M.Sc. (Agri.) Thesis, Univ. Agril. Sci*., Dharwad.

Paul. E. S. and C. H. William, 2008, Onion Production Guide. Edit George E. B. and W. T. Kelley. Cooperative Extension work, *The Uni. Georgia College of Agric. and Environ. Sci. and the U.S. Dept. Agric. cooperating.* B **2**:1198.

Pérez-Gregorio, R. M., García-Falcón, M. S., Gándara, S. J., Rodrigues, A. S., Almeida D. P. F. 2010, Identification and quantification of flavonoids in traditional cultivars of red and white onions at harvest. *J. Food Compos Anal.*, **23**: 592-598.

Popova, L., Pancheva, T., Uzunova, A., 1997. Salicylic acid: properties, biosynthesis and physiological role. Bulg. *J. Plant Physiol.* **23**: 85–93.

Pramanick, K. K., Narendra, S., Netrapal, N. S. and Singh, N., 1989, Physiological aspect on growth, yield and storage qualities of onion (*Allium cepa* L.). *Indian J. Agric. Sci.*, **69**(2): 126-129.

Rabinowitch, H. O., and Currah, L. 2002. *Allium Crop Science: Recent Advances*. CABI Publishing, UK. 585p.

Ram, R. B., Meena, M. L., Lata, R. and Yadav, H. H., 2012, Effect of post harvest treatments and storage condition on shelf life and quality of AONLA cv. NA-6. *Progressive Agri*., **11**(2): 305-310.

Ramin, A. A., 1999, Storage potential of bulb onions (*Allium cepa* L.) under high temperatures. *J. Hortic. Sci. Biotechnol*., **74**: 181-186

Randle, W. M. and Bussard, M. L., 1993, Pungency and sugar of short-day onion as affected by sulphur nutrition. *J. Am. Soc. Hortic. Sci.*, **118:** 766–770.

Randle, W. M. and Bussard, M. L., 1993, Streamlining onion pungency analysis. *Hort. Sci.*, **20**: 221-226.

Randle, W. M., 1992, Sulphur nutrition affects nonstructural water-soluble carbohydrates in onion germplasm. *Hort. sci.*, **27**: 52-55.

Randle, W. M., 1997, Onion flavour chemistry and factors influencing flavour chemistry. In: Risch, S., J. and Ho, C.-T. (Eds.) *Spices: Flavour chemistry and antioxidant properties*. American Chemical Society, Washington.

Randle, W. M., Lancaster, J. E., 2002, Sulphur compounds in Alliums in relation to flavour quality. In rabinowitch, H. D., Currah, L. (Eds.), *Allium Crop Science: Recent Advances* (p. 329-356). Wallingford, UK: CAB International.

Randle, W. M., Lancaster, J. E., Shaw, M. L., Sutton, K. H., Hay, R. L., and Bussard, M. L. (1995). Quantifying onion flavor compounds responding to sulfur fertility-sulfur increases levels of alk(en)yl cysteine sulfoxides and biosynthetic intermediates. *J. Am. Soc. Hortic. Sci.*, **120**(6): 1075-1081.

Ranjbaran, E., Hassan, S., Akira, W. and Davood, B., 2011, Effect of salicylic acid on storage life and postharvest quality of grape (*Vitis vinifera* L. cv. 'Bidaneh Sefid'). *J. Fac. Agric. Kyushu Univ.*, **56**(2): 263- 269.

Rao, M. V, Paliyath G, Ormrod, D. P, Murr D. P. and Watkins, C. B. 1997. Influence of salicylic acid on H2O2 production, oxidative stress, and H_2O_2-metabolizing enzymes. *Plant Physiol.*, **115**: 137–149.

Raskin, I., 1992a. Role of salicylic acid in plants. Ann. Rev. *Plant Physiol. Plant Mol. Biol.* **43**: 439–463.

Raskin, I., 1992b. Salicylate, a new plant hormone. *Plant Physiol*. **99**: 799–803.

Raskin, I., Turner, I. M., and Melander, W. R., 1989, Regulation of heat production in the inflorescences of an Arum lily by endogenous salicylic acid. PNAS, **86:** 2214-2218.

Reddy, P., Ninganur, B.T., Chetti, M.B. and Hiremath, S. M., 2009, Effect of growth retardants and nipping on chlorophyll content, nitrate reductase activity, seed protein content and yield in cowpea (*Vigna unguiculata* L.) Karnataka *J. Agri. Sci.*, **22**(2): 289-292.

Robak, J., and Adamicki, F, 2007, The effect of pre-harvest treatment with fungicide on the storage potential of root vegetables, **67:** 187- 196.

Roldán-Marín, E., Sánchez-Moreno, C., Lloría, R., De Ancos, B., Cano, M. P., 2009, Onion high-pressure processing: Flavonol content and antioxidant activity. *LWT-Food Sci. Technol.*, **42**: 835-841.

Rutherford, P. P. and Whittle, R., 1982, The carbohydrate composition of onions during long term cold storage. *J. Hort. Sci.*, **57**: 349- 356.

Sadasivam, S. and Manickam, A., 2005, Biochemical methods. New age international publishers, Second edition. p. 193-194.

Saimbhi, M. S. and Randhawa, K. S., 1982, Losses in white onion variety Punjab-48 under ordinary storage conditions as influenced by bulb size. *J. Res Ind.,* **19**: 188-190.

Sakhabutdinova, A. R., Fatkhutdinova, D. R., Bezrukova, M. V., and Shakirova, F. M., 2003, Salicylic acid prevents the damaging action of stress factors on wheat plants. *Bulg. J. Plant Physiol.,* 314–319.

Salama, A. M., Hicks, J. R. and Nock, J. F. (1990). Sugar and organic acid changes in stored onion bulbs treated with maleic hydrazide. *Hort. sci.*, **25**: 1625-1628.

Saltveit, M. E., 1993, Respiratory metabolism. Mann Laboratory, Department of Vegetable Crops, University of California, Davis, CA. www.ba.ars.usda.gov/hb66/respiratory metab.pdf

Sandhu, J. S., Thakur, J. C. and Nandpuri, K. S., 1976, Studies on the storage quality of red and white onion (*Allium cepa* L.) varieties. *J. Research*, **13**(3): 279-282.

Sanguansri, P. and Gould, I.V., 1990, Onion: artificial curing system and objective quality evaluation. *Proceedings of Agricultural Engineering Conference*, Toowoomba Australia, 11-14 November, **90**: 13.

Sankar, V. and Lawande, K. E., 2011, Effect of foliar application of growth retardant on growth and yield of garlic var. G-41. *Nat. Symp. on Alliums : Cur. Scenario and Emerging Trend*, 12-14 March 2011, DOGR, Rajgurunagar, Pune, p. 226.

Santiago, S. E., Eligio, D. T. Alberto, R. T. and Miller, S. A. 2003. Retarding bulb rot incidence in onion with selected curing and storage methods. *J. Tropical Plant Patho.* **39**(1 and 2): 81.

Satish, S.V. and Ranganna, B., 2002a, Development of hot air drying for bulk curing of onion. *Mysore J. Agric. Sci.*, **36**: 165-170.

Satish, S. V. and Ranganna, B., 2002b, Effect of curing on the physical and mechanical properties of onion. *Mysore J. Agric. Sci.*, **36**: 266-269.

Sayyari, M., Babalar, M., Kalantari, S., Serrano, M., and Valero, D. (2009). Effect of salicylic acid treatment on reducing chilling injury in stored pomegranates. *Postharvest. Biol. Technol.*, **53**: 152-154.

Schroeder, B. K., Humann, J. L., and Toit, L. J., 2012, Effects of post-harvest onion curing parameters on the development of sour skin and slippery skin in storage. *Plant Dis.*, **96**: 1548- 1555.

Schwimmer, S. and Guadagni, D.G. (1962). Relation between olfactory threshold concentration and pyruvic acid content of onion juice. *J. Food Sci.*, **27**: 94-97.

Schwimmer, S. and Weston, W. J., 1961, Enzymatic development of pyruvic acid in onion as a measure of pungency. *J. Agri. Food Chem.,* **9**: 301- 304.

Senaratna, T., Touchell, D., Bunn, E., Dixon, K., 2000, Acetyl salicylic acid (aspirin) and salicylic acid induce multiple stress tolerance in bean and tomato plants. *Plant Growth Regul*. **30**: 157–161.

Shafiee, M. Taghavi, T.S and Babalar, M., 2010, Addition of salicylic acid to nutrient solution combined with postharvest treatments (hot water, salicylic acid, and calcium dipping) improved postharvest fruit quality of strawberry. *Sci. Hortic.*, **124:** 40–45.

Shaha, S.R., Kale, P.N. and Patil, J.V., 1992, Path coefficient analysis in onion and evaluation for storage quality. *Maharashtra J Hortic.*, **6**(2): 43-47.

Shivakumar and Chandrashekar S.Y. 2014, Physio-chemical changes during post harvest handling of onion (*allium cepa* l.)–a review. *Agric. Rev.*, **35**(3): 225-232.

Shulaev, V., Silverman, P. and Raskin, I. (1997). Air borne signaling by methyl salicylate in plant pathogen resistance. *Nature*, **385**: 718-721.

Sidhu, A. S. and Chadha, M. L., 1986, Studies on the storage life of *kharif* onion. *Indian Food Packer*, **40**(1-2): 69-72.

Sidhu, A. S., 2008, Storage potential of some onion and garlic cultivars: A comparative evaluation. *Indian J. Hort.*, **65**(3): 347- 348.

Simon, P. W., 1995, Genetic analysis and total soluble solids in long storage onion. *Euphytica,* **82**: 1–8.

Sinclair, P. J., Blakeney, A. B. and Barlow, E. W. R. (1995). Relationships between bulb dry matter content, soluble solids concentration and non-structural carbohydrate composition in the onion. *J. Sci. Food Agri.*, **69**: 203-209.

Singh, B. N., Singh, B. R., Singh, L., Prakash D., Singh, D.P., Sarma, B. K. and Upadhyay, G., Singh, B., 2009, Polyphenolics from various

extracts/fractions of red onion (Allium cepa) peel with potent antioxidant and antimutagenic activities. *Food Chem. Toxic.,* **47**: 1161-1167.

Singh, J. and Dhankhar, B.S., 1995, Effect of pre-harvest chemical treatment on storage loss of onion. *Adva Horti For.*, **4**: 119-126.

Singh, J., Kavel, J. N. and Brar, Z. S., 1993, Compartmentation of canopy dry matter and seed yield of summer mung bean in relation to irrigation and cycocel regimes. *Indian J. Pulses Res.*, **6**: 207-209.

Singh, K. K., Singh, M. P., Sharma, C. P. and Singh., D. B., 1982, Effect of growth regulators along With nitrogen and potash on growth and yield of onion (*Allium cepa* L.), *JNKVV Res. J.*, **16**: 3.

Singh, K. V., Singh, B., Deepak Kumar, Braj Mohan and Pal, M. K., 2008, Effect of growth regulators on growth and yield of garlic (*Allium sativum* L.). *Prog. Agric.*, **8**(2): 154-156.

Singh, S., 2011, Effect of cycocel, potassium sulphate and benlate on morphology and fruit quality in ber (*Ziziphus mauritiana*) cv. Banarasi Karaka. *Asian J. Hortic.*, 6 (2): 335-338.

Singhal, S. C., 2000, Export of onion – Challenges and strategies. *Souvenir, National Symposium on Onion and Garlic Production and Post-harvest Technology Management: Challenges and Strategies*, 19-21 November 2000, National Research Centre for Onion and Garlic, Rajgurunagar, Nasik, pp. 49-64.

Slaymaker, D. H., Navarre, D. A., Clark, D., Del Pozo, O., Martin, G. B. and Klessig, D. F., 2002. The tobacco salicylic acid-binding protein (3 SABP3) is the chloroplast carbonic anhydrase, which exhibits antioxidant capacity and plays a role in the hypersensitive response. Proceedings of the National Academy of Sciences, USA **99**: 11640–11645.

Snowdon, A. L., 1990, A colour atlas of postharvest disease and disorders of fruits and vegetables. Vol 1: General introduction and fruits . Boca Ratoon, FL CRC Press. pp. 302.

Sonawane, H.S., Pujari, K.H., Ghavale, S.L. and Nawale, R. N., 2016, Studies on effect of foliar sprays of paclobutrazol and cycocel on flowering behaviour of mango *cv.* Alphonso. *Nat. Aca. Agric. Sci.,* **34**(2): 471-477.

Srinivasan, V. M., Krishnamoorthy. A. S., Kuttalam. S., Raguchander. T. and Chinnamuthu.C.R, 2014, Performance evaluation of azoxystrobin in the control of fruit rot and powdery mildew diseases on chilli. *Sci Park Res J.,* **36**(1): 67-74.

Srivastava, M. K. and Dwivedi, U. N., 2000, Delayed ripening of banana fruit by salicylic acid. *Pla. Sci.,* **158**: 87-96.

Srivatava, P. K. and B. K. Tiwari, 1997, Effect of pre-harvest fungicidal spray on the control of storage diseases of onion. News Letter, *Natl. Hort. Res. and Dev. Found.,* **17**(2): 4-6.

Sundravadana, S., Alice, D., Kuttalam, S. and Samiyappan, R., 2006, Efficacy of azoxystrobin on *Colletotrichum gloeosporiodes* growth and on controlling mango anthracnose. *J. Agri. Biol. Sci.,* **3**(2): 10- 15.

Supriya, A.T., 2015, Studies on influence of pre-harvest foliar sprays on storage life and quality of onion var. Arka Kalyan. M.Sc. Thesis, Department of Post Harvest Technology, University of Horticultural Sciences, Bagalkot. (Unpublished)

Suzuki, M. and Cutliffe, J. A. 1989, Fructans in onion bulbs in relation to storage life. *Canadian J. Plant Science*, **69**: 1327-1333.

Tareen, M., Abbasi, M. and Hafiz, I., 2012, Effect of salicylic acid treatments on storage life of peach fruits cv. '*Florda king'. Pak. J. Bot*., **44**(1): 119-124.

Tariq, A., B. Abdul and M. Khan., 2005, Assessment of post harvest losses of onion bulbs during storage at room condition. *J. Agric.* **21**(2): 189-191.

Terry, L. A., Law, K. A., Hipwood, K. J. and Bellamy, P. H. (2005). Non-structural carbohydrate profiles in onion bulbs influence taste preference. In: *Frutic*

05, Information and technology for sustainable fruit and vegetable production, 12-16 September 2005, Montpellier, France.

Thakur, N. S., Sharma, S., Joshi, V. K., Thakur, K. S. and Jindal, N., 2012, Studies on drying, packaging and storage of solar tunnel dried chilogoza nuts. *Arc. Appl. Sci. Res.,* **4**(3): 1311- 1319.

Thamizharasi, V., Narasimham, P. 1992: Growth of *Aspergillus niger* on onion bulbs and its control by heat and sulphur dioxide treatments. *Trop. Sci*., **33**: 45-55.

Thampson, A. K., Booth, R. H. and Proctor, F. J., 1972, Onion storage in tropics. *Tropic. Sci.,* **14**(1): 19-34.

Thomas, T. H. and Rankin, W. E. F. 1982, Effect of ethephon on bulbing, bull-necking, yield and sprouting during storage of two onion cultivars *(Allium cepa* L.). *J. Hortic. Sci.*, **57**: 465–467.

Thomas, T. H., Isenberg, F. M. R. Hormone physiology of onion bulbs during dormancy. *Exp Hortic*. 1972, **23:** 48–51.

Thomas, T.H. 1969, The role of growth substances in the regulation of onion bulb dormancy. *J. Exp. Bot*., **20:**124–137.

Toul, V. and Pospisilova, P., 1968, The chemical composition of onion varieties. *Plant Breed Abstr.,* **38**(3): 679.

Trevisan, J. N., Martins, G. A. K., Lopes, S. J. and Garcia, D. C., 1999. Yield and post harvest storability of lowland grown onion genotypes. *Ciencia Rural*. **29**(3): 409-413.

Tripathi, P. C. and Lawande, K. E., 2003, Onion storage structure for small and marginal farmers. ICAR News, *A Science and Technology Newsletter*, **9**(4): 18- 19.

Trushin, M. V., Ratushnyak, A. Y., Arkharova, I. R. and Ratushnyak, A. A., 2013, Genetic alterations revealed in *Allium cepa*-test system under the action of some xenobiotics. *World Appl Sci J.* **22**(3): 342- 344.

Tsewang, R., 2016, Effect of seedling dip and pre-harvest spray of chemicals on storage behaviour of onions cv. Arka Kalyan. M.Sc. Thesis, Department of Post Harvest Technology, University of Horticultural Sciences, Bagalkot. (Unpublished data).

Tucker, W. G. The sprouting of bulb onions in store. *Acta. Hortic*. 1989, **258**: 485–492.

Uddin, M. and MacTavish, H. S. (2003). Controlled atmosphere and regular storage induced changes in S- alk(en)yl-L-cysteine sulfoxides and alliinase activity in onion bulbs (*Allium cepa* L. cv. Hysam). *Postharvest. Biol. Technol.,* **28:** 239-245.

Uzunova, A. N., Popova, L. P., 2000, Effect of salicylic acid on leaf anatomy and chloroplast ultra structure of barley plants. *Photosynthetica,* **38**: 243–250.

Valero, D., Diaz-Mula, H. M., Zapata, P. J., Castillo, S., Guillen, F. and Martinez-Romero, D. and Serrano, M., 2011, Post-harvest treatments with salicylic acid, acetylsalicylic acid or oxalic acid delayed ripening and enhanced bioactive compounds and antioxidant capacity in sweet cherry. *J. Agric. Food Chem.,* **59**: 5483-5489.

Vijayakumar, R.M., Sundararajan, S. and Kumar, N., 1987, Effect of growth regulators on the post-harvest physiology of small onion. *South Indian Hortic.,* **35**(4): 299-303.

Vincelli P., 2002, Q_O I (Strobilurin) Fungicides: Benefits and Risks. *The Plant Health Instructor*. **10**(2): 809-1094.

Vintila, M., Niculescu, F.A. and Romas, M. (2014). Technical Aspects Regarding the Preservation of Dry Onions in Different Storage Conditions. *Bulletin UASVM Food Sci. Technol.,* **71**.

Vlot, A. C., Dempsey, D. A. and Klessig, D. F., 2009, Salicylic acid, a multifaceted hormone to combat disease. *Ann. Rev. Phyto. Pathol*., **47**: 177-206.

Wang, L., Chen, S., Kong, W., Li, S., and Archbold, D. D. (2006). Salicylic acid pretreatment alleviates chilling injury and affects the antioxidant system and

heat shock proteins of peaches during cold storage. *Postharvest. Biol. Technol.*, **41**: 244-251.

Warade, S. D., Desale, S. B. and Shinde, K. G., 1997, Effect of different storage recommendation on storability of onion bulbs. *J. Maharashtra Agric. Univ.*, **22**(3): 283-285.

Wedge, D. E., Smith, B. J., Quebedeauxc, J. P. and Constantin, R. J., 2007, Fungicide management strategies for control of strawberry fruit rot diseases in Louisiana and Mississippi. *Crop. Prot.*, **26**: 1449- 1458.

Wheeler, T. R., Daymond, A. J., Ellis, R. H., Morison, J. I. L. and Hadley, P., 1998, Post-harvest sprouting of onion bulbs grown in different temperature and CO_2 environments in the UK. *J. Hortic. Sci Biotech.*, **73**: 750-754.

Whitaker, J. R., 1976, Development of flavor, odor and pungency in onion and garlic. *Adva. Food Res.*, **22**: 73-133.

Wickramasinghe, U. L., Wright., C. J. and Currah, L. (2000). Bulbing responses of two cultivars of red tropical onions to photoperiod, light integral and temperature under controlled growth conditions. *J. Hortic. Sci. Biotech.*, **75**: 304-311.

Woldetsadik, S. K. and Workneh, T. S., 2010, Effects of Nitrogen Levels, Harvesting Time and Curing on Quality of Shallot Bulb. *African J. Agri. Res.*, **5**: 3342-3353.

Wright, P. J., 1993. Effects of nitrogen fertiliser, plant maturity at lifting, and water during field-curing on the incidence of bacterial soft rot of onions in store. *New Zealand J. Crop Hort. Sci*., **21**(4): 377-381.

Wright, P.J. and Grant, D.G., 1997, Effect of cultural practices at harvest on onion bulb quality and incidence of rots in storage. *New Zealand J. Crop Hort. Sci*., **22**(4): 353-358.

Xuang, L. C., Jun, Y., Cai, W. S., Kai, Z., Jun, L. S. and Xie, Z., 2001, The role of Salicylic acid in the swelling of garlic (*Allium sativum* L.) bulb. *Plant Growth Regulator Abstr.,* **27**(4): 333.

Xuequn, S., Boqiang, L., Guozheng, Q. and Shiping, T., 2012, Mechanism of antifungal action of borate against *Colletotrichum gloeosporioides* related to mitochondrial degradation in spores. *Postharvest Biol. Technol.,* **67**: 138-143.

Yadav, S. S. and Yadav, V. V. A., 2011, Comparative study on different types of structures for onion storage. *Veg. Sci.,* **38**(1): 92- 94.

Yalpani, N., Enyedi, A. J., Leon, J. and Raskin, I., 1994, Ultraviolet light and ozone stimulate accumulation of salicylic acid, pathogenesis-related proteins and virus resistance in tobacco. *Planta.,* **193**: 372–376.

Yang D. L., Yang, Y. and He, Z., 2013, Roles of plant hormones and their interplay in rice immunity. *Mol. Plant.,* **6:** 675–685.

Yao, H. and Tian, S., 2005, Effects of pre- and post-harvest application of salicylic acid or methyl jasmonate on inducing disease resistance of sweet cherry fruit in storage. *Postharvest. Biol. Technol.*, **35**:253–262.

Yeganeh, M., Hadavi, E. and Kalhori, M., 2013, Effects of salicylic acid on quality of 'Bidaneh Sefid' table grapes during cold storage. *Int. J. Agri. Crop Sci.,* **5**(18): 2041-2047.

Yoo, K. S., Lee, E. J. and Patil, B. S., 2012, Changes in flavor precursors, pungency, and sugar content in short-day onion bulbs during 5-month storage at various temperatures or in controlled atmosphere. *J. Food Sci.* **77**(2): 216-222.

Zhang, Y., Chen, K., Zhang, S. and Ferguson, I., 2003, The role of salicylic acid in post-harvest ripening of kiwifruit. *Postharvest Biol Technol.,* **28**(1): 67-74.

Zheng, Y. and Zhang, Q., 2004, Effects of Polyamines and Salicylic Acid on Postharvest Storage of ‘Ponkan’ Mandarin. *Acta. Hort.,* 632.

Zhu, F., Chen, J., Xiao, X., Zhang, M., Yun, Z., Zeng Y., Xu, J., Cheng, Y. and Deng X., 2016, Salicylic acid treatment reduces the rot of postharvest citrus fruit by inducing the accumulation of H_2O_2, primary metabolites and lipophilic polymethoxylated flavones. *Food Chem.,* **207:** 68–74.

Zinzala, M. R., Bhalerao, P.P. and Patil. S.J., 2017. Effect of foliar application of plant growth regulators on growth, yield and quality of garlic (*Allium sativum* L.) var. GG-3. *Int. J. Appli. Agric. Hortic. Sci.* **8**(2)**:** 483-485.

Appendix I: Weekly average temperature and relative humidity (RH) recorded in laboratory, Department of Post Harvest Technology, College of Horticulture, Bagalkot during the period of storage studies for 3 months (22-01-2017 to 27-05-2017)

Weeks	Laboratory	
	Temperature (°C)	Relative humidity (RH)
22-01-2017 to 28-01-2017	22.20	49.70
29-01-2017 to 04-02-2017	25.40	46.50
05-02-2017 to 11-02-2017	25.90	42.70
12-02-2017 to 18-02-2017	26.10	49.90
19-02-2017 to 25-02-2017	21.70	41.20
26-02-2017 to 04-03-2017	28.90	32.80
05-03-2017 to 11-03-2017	29.60	30.80
12-03-2017 to 18-03-2017	32.60	39.10
19-03-2017 to 25-03-2017	34.70	40.40
26-03-2017 to 01-04-2017	34.50	37.30
2-04-2017 to 08-04-2017	35.00	45.00
09-04-2017 to 15-04-2017	35.40	43.00
16-04-2017 to 22-04-2017	29.30	40.30
23-04-2017 to 29-04-2017	29.20	36.90
30-04-2017 to 6-05-2017	27.40	41.00
07-05-2017 to 13-05-2017	27.60	40.10
14-05-2017 to 20-05-2017	29.00	44.00
21-05-2017 to 27-05-2017	29.10	44.30
Mean	29.09	41.38

Appendix II: Cost of raw materials used in research

Sl. No	Items	Price
1.	Azoxystrobin(Amitstar)	1358/200 ml
2.	Cycocel	650/500 ml
3.	Salicylic acid	804/500gm
4.	Onion seed	1000/500 gm

STUDIES ON FIELD APPLICATION OF SALICYLIC ACID, AZOXYSTROBIN AND CYCOCEL ON SHELF LIFE OF ONION VAR. ARKA KALYAN

AYEESHYA H. KOLHAR **2017** **Dr. S. L. JAGADEESH**
Major Advisor

ABSTRACT

The present investigation entitled "Studies on field application of salicylic acid, azoxystrobin and cycocel on shelf life of onion cv. Arka Kalyan" was conducted in the Department of Post Harvest Technology, COH, Bagalkot, Karnataka during the year 2016-2017. Onion cv. Arka Kalyan was imposed with seedling dip and pre-harvest foliar sprays at different time intervals at 60 and 90 days after transplanting (DAT). After harvesting bulbs were cured properly and stored under ambient condition. Various physiological and physico-chemical changes were recorded at monthly intervals for 4 months. Treatments showed significant differences for yield, number of bulbs per kg and bulb diameter. Foliar spray of salicylic acid (SA) @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT followed by CCC 2500 ppm foliar spray @ 90 DAT (T_{11}) significantly reduced the physiological loss in weight (PLW) (11.62%), and bulbs of the treatment T_3 (Seedling dip in SA @ 2 mM + SA @ 2 mM 60 + 90 DAT) exhibited least rate of respiration (15.29 ml CO_2/Kg/h). Minimum sprouting was observed in the treatment T_{12} (Seedling dip in salicylic acid @ 2 mM + SA @ 2 mM, azoxystrobin @ 0.1% at 60 + 90 DAT and CCC 2500 ppm at 90 DAT) (2.26%) and bulbs of the treatment T_5 (SA @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT) exhibit least rotting (1.87%). Reduced incidence of black mould was noticed in the treatment T_{12} (1.63%) and maximum per cent marketable were obtained in the treatment T_{11} (85.54%).

The Maximum mean dry matter (18.38%) and minimum per cent moisture (81.60%) was noticed in treatment T_4 (Pre-harvest spray of azoxystrobin @ 0.1% at 60 + 90 DAT). Bulbs of the treatment T_{11} were found to be more firmner (123.38 N), contained more total solubule solids (15.14 °B) and bulbs scored maximum for overall acceptability(7.90 out of 9)

Pyruvic acid, indicating pungency was noted to be maximum in T_6 (Seedling dip SA @ 2 mM + SA @ 2 mM and azoxystrobin @ 0.1% at 60 + 90 DAT) (8.71 µmoles/g) and the same treatment recorded maximum total phenol (13.73 mg/100g). In conclusion, foliar application of SA (2 mM), azoxystrobin (0.1%) at 60 + 90 DAT and CCC (2500 ppm) at 90 DAT was effective in maintaining quality and shelf life of onion.

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FgÀÄ½î (vÀ½ CPÁð PÀ¯Áåt) AiÀÄ ¸À¹UÀ¼À£ÀÄß ¸Áå°¹°Pï DªÀÄèzÀ°è G¥ÀZÀj¹ ºÁUÀÆ ¨É¼ÉAiÀÄ£ÀÄß ««zsÀ gÁ¸ÁAiÀÄ¤PÀUÀ¼ÁzÀ ¸Áå°¹°Pï DªÀÄè, CeÉÆÃQì¸ÉÆÖçÃ©£ï ªÀÄvÀÄÛ ¸ÉÊPÉÆ¹¯ïUÀ½AzÀ £Án ªÀiÁrzÀ 60 ªÀÄvÀÄÛ 90 ¢£ÀUÀ¼À CAvÀgÀzÀ°è ¹A¥ÀgÀuÉ ªÀiÁqÀ¯Á¬ÄvÀÄ. PÉÆ¬Äè£À £ÀAvÀgÀ FgÀÄ½îAiÀÄ£ÀÄß ZÉ£ÁßV ¸ÀA¸Àlj¹ CªÀÅUÀ¼À£ÀÄß ¸ÁªÀiÁ£Àå ªÁvÁªÀgÀtzÀ°è £Á®ÄÌ wAUÀ¼ÀÄUÀ¼À PÁ® ±ÉÃRj¹qÀ¯Á¬ÄvÀÄ.

F ªÉÄÃ°£À G¥ÀZÁgÀUÀ½AzÀ E¼ÀÄªÀj, FgÀÄ½AiÀÄ ¸ÀASÉå/Q.UÁæA. ºÁUÀÆ FgÀÄ½îAiÀÄ ªÁå¸ÀzÀ°è UÀªÀÄ£ÁºÀð ªÀåvÁå¸À PÀAqÀÄ§A¢zÉ. G¥ÀZÁgÀ T_{11} (¸Áå°¹°Pï DªÀiïè @ 2 mM, CeÉÆÃQì¸ÉÆÖçÃ©£ï @ 0.1 % £Án ªÀiÁrzÀ 60 ªÀÄvÀÄÛ 90 ¢£ÀUÀ¼À £ÀAvÀgÀ ºÁUÀÆ ¸ÉÊPÉÆ¹¯ï @ 2500 ppm £Án ªÀiÁrzÀ 90 ¢£ÀUÀ¼À £ÀAvÀgÀ) gÀÀ°è PÀrªÉÄ ±ÁjÃjPÀ vÀÆPÀ £ÀµÀÖ (11.62%), ºÉZÀÄÑ ªÀiÁgÀÄPÀmÉÖ AiÉÆÃUÀå FgÀÄ½îUÀ¼ÀÄ (85.54%), C¢üPÀ n.J¸ï.J¸ï. (¸ÀPÀÌgÉ CA±À), UÀnÖvÀ£À (Firmness) (123.98 N) ºÁUÀÆ gÀ¸À¸ÁézÀ ªÀiË®å ªÀiÁ¥À£ÀzÀ°è MlÄÖ ºÉZÀÄÑ ¹éÃPÀgÁºÀðvÉ (7.90) AiÀÄ£ÀÄß £ÉÆÃqÀ¯Á¬ÄvÀÄ.

G¥ÀZÁgÀ T_{12} (2 mM ¸Áå°¹°Pï DªÀÄèzÀ°è ¸À¸ÉÆåÃ¥ÀZÁgÀ ªÀÄvÀÄÛ ¸Áå°¹°Pï DªÀÄèè @ 2 mM, CeÉÆÃQì¸ÉÆÖçÃ©£ï @ 0.1 % £Án ªÀiÁrzÀ 60 ªÀÄvÀÄÛ 90 ¢£ÀUÀ¼À £ÀAvÀgÀ ºÁUÀÆ ¸ÉÊPÉÆ¹¯ï @ 2500 ppm £Án ªÀiÁrzÀ 90 ¢£ÀUÀ¼À £ÀAvÀgÀÀ) gÀÀ°è PÀrªÉÄ ªÉÆ¼ÀPÉ ¥ÀæªÀiÁt (2.26%) ºÁUÀÆ PÀ¥ÀÄà §Æ¸ïÖ (1.63%) PÀAqÀÄ §gÀÄvÀÛzÉ. DzÀgÉ T_5 (¸Áå°¹°PÀ DªÀÄè @ 2 mM, CeÉÆÃQì¸ÉÆÖçÃ©£ï @ 0.1 % £Án ªÀiÁrzÀ 60 ªÀÄvÀÄÛ 90 ¢£ÀUÀ¼À £ÀAvÀgÀ) gÀÀ°è G¥ÀZÀj¹zÀ FgÀÄ½îAiÀÄ°è PÀrªÉÄ PÉÆ¼ÉAiÀÄÄ«PÉ (1.87%) AiÀÄ£ÀÄß UÀªÀÄ¤¸À¯Á¬ÄvÀÄ. £Án ªÀiÁrzÀ 60 ªÀÄvÀÄÛ 90 ¢£ÀUÀ¼À £ÀAvÀgÀ CeÉÆÃQì¸ÉÆÖçÃ©£ï @ 0.1 %

G¥ÀZÀgÀ£ÉAiÀÄ°è (T_4), FgÀÄ½î UÀqÉØUÀ¼ÀÄ CvÀå¢üPÀ MtgÁ² (Drymatter) (18.38%) ºÁUÀÆ PÀrªÉÄ vÉÃªÁA±À (81.60%) ªÀ£ÀÄß ºÉÆA¢ªÉ.

SÁgÀzÀ ¸ÀAPÉÃvÀªÁzÀ ¥ÉÊgÀÄ«Pï DªÀÄèªÀÅ G¥ÀZÁgÀ T_6 (¸À¹UÀ¼À G¥ÀZÁgÀ @ 2 mM ªÀÄvÀÄÛ ¸Áå°¹°Pï DªÀiïè @ 2 mM, CeÉÆÃQì¸ÉÆÖçÃ©£ï @ 0.1 % £Án ªÀiÁrzÀ 60 ªÀÄvÀÄÛ 90 ¢£ÀUÀ¼À £ÀAvÀgÀ) £À°è ºÉZÀÄÑ ¥ÀæªÀiÁtzÀ°è (8.71 µmoles/g) PÀAqÀÄ§A¢zÉ EzÀgÀ eÉÆvÉUÉ EzÉÃ G¥ÀZÁgÀzÀ°è MlÄÖ ¦üÃ£Á¯ï (13.73 mg/100g) PÀÆqÀ C¢üPÀªÁVzÉ. MmÁÖgÉAiÀiÁV FgÀÄ½îAiÀÄ°è £Án ªÀiÁrzÀ 60 ªÀÄvÀÄÛ 90 ¢£ÀUÀ¼À £ÀAvÀgÀ ¸Áå°¹°Pï DªÀÄè @ 2 mM, CeÉÆÃQì¸ÉÆÖçÃ©£ï @ 0.1 % ºÁUÀÆ ¸ÉÊPÉÆ¹¯ï @ 2500 ppm £Án ªÀiÁrzÀ 90 ¢£ÀUÀ¼À £ÀAvÀgÀzÀ G¥ÀZÀgÀ£ÉAiÀÄ°è FgÀÄ½îAiÀÄ UÀÄtªÀÄlÖ ºÁUÀÆ ±ÉÃRgÀuÉAiÀÄ°è ¥Àæ¨sÁªÀPÁj ¥ÀjuÁªÀÄ ©ÃjzÉ JAzÀÄ F ¸ÀA±ÉÆÃzsÀ£É¬ÄAzÀ w½zÀÄ§gÀÄvÀÛzÉ.