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Garlic (*Allium sativum*) storage in tropical region–a review

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Abstract

Garlic (*Allium sativum*) is one of the important spices used worldwide in different cuisines. Garlic is grown in one season but its demand is around the year. Thus A large quantity of garlic is stored to fulfill the demand during off season. The storage losses of garlic in temperate region are lower as compared to tropical region. The storage losses of garlic is higher in tropical region due to higher temperature and humidity during storage period. These losses may be 15 to 40 percent which includes physiological weight loss(PLW), rotting and sprouting. There are several reasons of higher storage losses such as genetic makeup of cultivars, type of manure and fertilizer and their time of application and quality, quantity, method and time of application of water, pre harvest treatments, harvesting time , field curing, drying, store environment, storage structures etc.. There are two distinct temperature regimes where losses are minimum. One is high temperature regime, where storage temperature is 25-30^{0}C and another is low temperature regime, where temperature is augmented maintained 0 to 2^{0}C. Best results under both the temperature regimes are obtained when humidity is maintained at 65 to 70 %. The storage losses in high temperature conditions (25-30^{0}C) are high (30-35%) but storage cost is low. Various research works carried out on assessment of losses and reduction of storage losses through pre and post harvest management and modification of storage environment in the tropical garlic growing regions of the world are summarized in this review article.

Keywords: Garlic, Storage, Tropical region, Physiological loss, Sprouting, Decay, Biochemical Change

Quite often, market witnesses glut of vegetables in the season, which leads to poor return to the growers (Pagaria and Swami, 2023). On the other hand, consumers are willing to pay high prices for vegetables in off-season. Vegetables can be cultivated in off-season, with the introduction of greenhouses technologies (Dodiya *et al.,* 2021), wherein temperature and humidity are modulated for desirable growth of vegetables (Singh *et al.*, 2007; Singh *et al.*, 2021). The production of vegetables round the year facilitates the growers to make the maximum use the resources and augment income from vegetable growing as compared to other agricultural crops (Singh and Kumarnag, 2023).

One such cost-effective, farmers-friendly technology is 'low tunnel'. Low tunnels are miniature structures producing greenhouse like effect. This type of structures cover rows of plants; therefore, they are also known as 'row cover' (Jayasurya *et al.*, 2021). Low tunnels are constructed with locally available material such as bamboo (Bhatt *et al.*, 2016) and wood or with GI wires, plastic or metal bars to form semi-circular frames, which are covered with thin plastic sheet (PE or PVC 30-50 μ) or with nylon screen (Kang *et al.*, 2013). The sides are secured down by placing them in soil or by side-to-side crisscrossing nylon rope anchored to the base of each pole; however, in the growing season, the sides are opened by lifting them up for improving ventilation or plastic is slit as the temperature increase within the tunnels (Jayasurya *et al.*, 2021). Such structures are erected to provide temporary protection to crops and usually no higher than 1 m in height. In general, the height of the tunnel is kept at 45-60 cm with 45-60 cm width.

Low tunnels are used to conserve warmth to stimulate germination and early growth of seedlings in winters, to protect the plants from frost injury, to improve the quality of the crops (Singh *et al.*, 2007), to provide protection from wind and rain damage in melon cultivation and in winter production (forcing production) of vegetables (Kang *et al.*, 2013). Further, low tunnel production of vegetables offers other advantages such as Garlic (*Allium sativum*) is an herb that is grown around the world. It belongs to family Alliaceae and onion, leeks, and chives are other important crops of this family. It is an integral part of most of the cuisines throughout the world. Apart from its use in cuisine, garlic has historically been used to alleviate pains, leprosy, deafness, diarrhoea, constipation, parasitic infection, fever, stomach ache etc. since long (Woodward, 1996; Tattelman 2005; Rana *et al.* 2011; Tripathi *et al.* 2013). Garlic is most commonly used for conditions related to the heart and blood system. The medicinal properties of garlic were mentioned in *Charaka-Samhita*- a well known ancient Indian medical book for management of heart disease and arthritis (Rivlin, 2001). In another ancient medical text, garlic was reported to be used against

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digestive diseases, exhaustion, parasites, and leprosy (Woodward, 1996).

Garlic is one of the oldest cultivated crops which were brought under cultivation almost 5000 year ago in Central Asia, China and India. Almost 150 countries of world cultivate garlic. Garlic is cultivated in about 1.65 million hectares with an annual global production of about 28.85 million metric tones. China is the largest producer of garlic in the world and accounts for 74per cent of total garlic production. India ranks second and produces 11per cent of the total production. The average productivity of the garlic in the world is 9.64 tones but the productivity in China is more than 25 tones per hectare. Other produces are Bangladesh, Spain and South Korea. The average productivity of the garlic is 13 tones but the productivity in China more than 25 tones /ha. More than 50 tropical countries produce garlic. India, Bangladesh, Ethiopia, Nigeria, Myanmar, Brazil, Pakistan etc. are major tropical garlic growing countries.

The tropical counties contribute around 39.38 % area and 19.05 percent of total production of garlic in the world. The productivity of temperate countries is 8.43 tons per hectare while the global productivity of garlic is around 9.65 tons/ ha (Table 1, Fig 1, 2&3; FAOSTAT, 2022). Most of these countries produce garlic for their domestic consumption and their contribution to global garlic trade is very less. India is the largest tropical garlic growing country. Madhya Pradesh and Rajasthan are the leading states in India contributing more than 50% in both area and production. The other major garlic growing states are Gujarat, Uttar Pradesh and Maharashtra (Table 2; Anonymous, 2022).

Though garlic was originated in temperate region but it is widely cultivated in tropical regions of the world. Although varieties grown in tropical and subtropical regions have different climatic requirements. The garlic gown in tropical regions has shorter duration, more pungency, and small cloves. Garlic is cultivated in only one season barring few exception. Thus a large quantity of garlic is stored for fulfilling the domestic and international requirements. Though garlic production season the southern hemisphere is different but the area and production in very little the hemisphere.

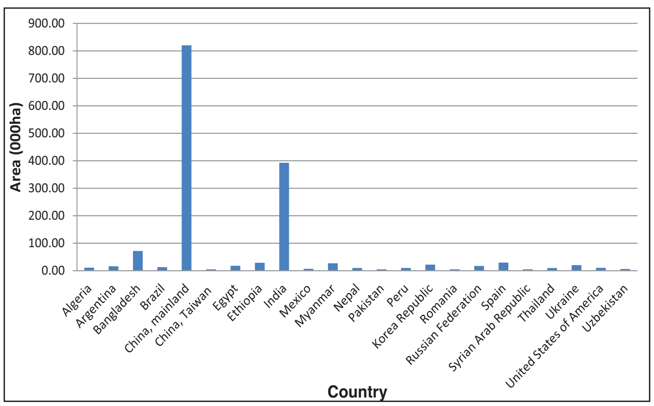

Fig 1. Area under garlic cultivation in major countries of world (2022)
(*Source*: FAOSTAT,2022)

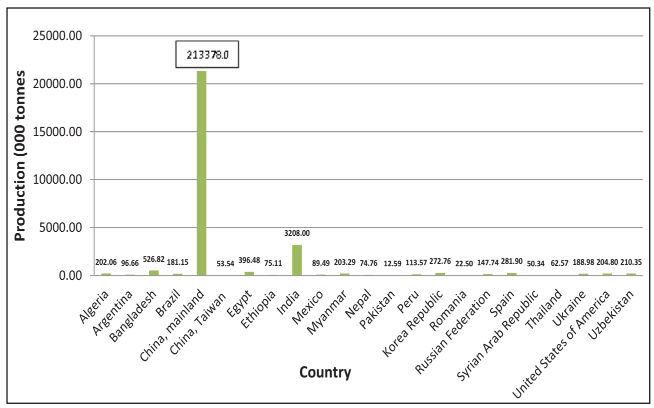

Fig 2. Production of garlic in major countries of world (2022)
(*Source:* FAOSTAT,2022)

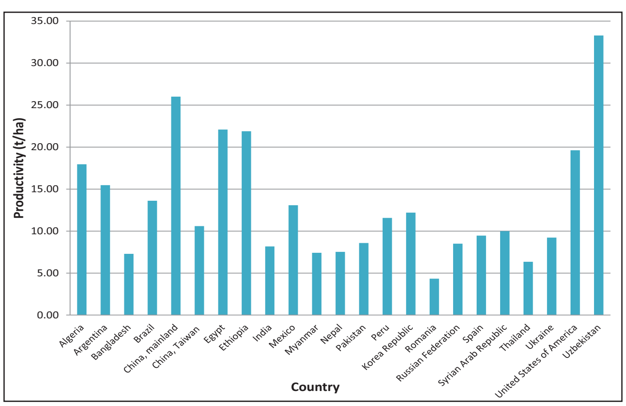

Fig 3. Productivity(ton/ha) of garlic in major countries of world (2022)
(*Source:* FAOSTAT,2022)

Table1. Major tropical garlic producing countries of the world (2022)

Country	Area ('000 ha)	Area (%)	Production ('000 tones)	Production (%)	Productivity (tones/ha)
Algeria	11.25	0.68	202.06	0.70	17.96
Angola	0.97	0.06	13.08	0.05	13.48
Argentina	16.00	0.97	96.66	0.34	15.47
Bangladesh	72.21	4.36	526.82	1.83	7.30
Bhutan	0.12	0.01	0.30	0.00	2.41
Bolivia	0.55	0.03	2.56	0.01	4.64
Brazil	13.31	0.80	181.15	0.63	13.62
Chile	1.78	0.11	21.65	0.08	12.19
Colombia	0.71	0.04	10.69	0.04	15.12
Cuba	1.71	0.10	10.69	0.04	6.25
Dominican Republic	0.40	0.02	3.02	0.01	7.62
Ecuador	0.84	0.05	1.29	0.00	1.53
Egypt	17.95	1.08	396.48	1.37	22.09
Ethiopia	29.13	1.76	75.11	0.26	21.88
Guatemala	3.39	0.20	29.98	0.10	8.86
India	393.00	23.72	3208.00	11.12	8.16
Indonesia	4.27	0.26	30.58	0.11	7.16
Libya	0.85	0.05	4.84	0.02	5.67
Madagascar	0.40	0.02	2.58	0.01	6.46
Malawi	0.11	0.01	0.74	0.00	6.50
Mali	1.31	0.08	18.10	0.06	13.87
Mauritius	0.01	0.00	0.05	0.00	7.00
Mexico	6.84	0.41	89.49	0.31	13.08
Morocco	2.66	0.16	11.18	0.04	4.21
Myanmar	27.41	1.65	203.29	0.70	7.42
Nepal	9.94	0.60	74.76	0.26	7.52
Niger	0.98	0.06	14.36	0.05	14.71
Nigeria	0.17	0.01	2.25	0.01	13.07
Pakistan	5.21	0.31	12.59	0.04	8.58
Paraguay	0.16	0.01	0.22	0.00	1.39
Peru	9.82	0.59	113.57	0.39	11.56
Sudan	3.25	0.20	28.42	0.10	8.76
Thailand	9.85	0.59	62.57	0.22	6.35
Tunisia	2.28	0.14	25.43	0.09	11.16
Tanzania	1.72	0.10	6.19	0.02	3.59
Uruguay	0.16	0.01	0.88	0.00	5.71
Venezuela	1.63	0.10	14.68	0.05	8.99
Total	**652.46**	**39.38**	**5497.71**	**19.05**	**8.43**

(*Source:* FAO STAT,2022)

Table2. Major garlic producing states in India (2021-22)

State	Area (000ha)	Production (000 tones)	Productivity (t/ha)
Assam	10.81	69.42	6.42
Bihar	1.41	2.21	1.56
Chhattisgarh	1.17	3.02	2.57
Gujarat	26.01	202.83	7.80
Haryana	3.42	39.91	11.69
Himachal Pradesh	6.94	13.58	1.96
Jammu & Kashmir	0.78	0.57	0.73
Karnataka	4.28	24.54	5.73
Kerala	0.19	1.02	5.25
Madhya Pradesh	204.68	2106.63	10.29
Maharashtra	4.05	24.35	6.02
Mizoram	0.02	0.01	0.53
Nagaland	0.28	2.32	8.35
Odisha	11.03	39.51	3.58
Punjab	8.88	97.04	10.93
Rajasthan	98.34	592.52	6.03
Tamil Nadu	1.93	11.18	5.78
Telangana	0.08	1.12	13.86
Uttar Pradesh	40.96	242.24	5.91
Uttarakhand	1.92	11.27	5.86
West Bengal	4.04	38.15	9.45
Total	431.22	3523.44	8.17

(*Source :* MOA&FW,GOI,New Delhi)

Garlic is produced only in one season i.e. winter season in most of the tropical regions. But some higher attitude regions of tropical areas such as high lands of Ethiopia , the Nilgiris hills of India growing garlic during March to September. In, Indian subcontinent, garlic is planted in October –November. It comes from February and continues up to March-April. In Southern hills particularly Nilgiri hills garlic is cultivated in two seasons i.e. March-April to July-August and also in October to March-April. In Northern hills it is cultivated in one season i.e. October to May-June.

More than 95% produce of garlic in tropical regions arrives in market in the months of March to May. But there is constant demand of garlic in the market as it is required daily in small quantity in almost all houses. Further, there is glut in the market during the harvest season. As a result farmers do not get the appropriate prices and they are forced to sale their produce at lower price. Thus it becomes essential to store garlic for regular supply in the market and to stabilize the price. It is estimated that more than one million tones of garlic is stored in tropical region to fulfill the domestic and export demand.

Storage losses

Garlic is less perishable crop as compared to other fresh vegetables. A well cured dried neck and outer skins prolong shelf life, although it will eventually sprout (end of dormancy), its metabolism will increase, and its quality will begin to change, making it more susceptible to attack by microorganisms and diseases (Brewster, 1994).The respiration of garlic during storage is lower than most of the vegetables. Thus the storage losses in garlic are comparatively lower and therefore it can be stored for longer period. The storage losses are directly related to genotypes and storage conditions. In most of the tropical countries, garlic is stored at room temperature and the storage losses are higher at these conditions. These may range between 35 - 40 percent for a period of 6 to 8 months. Tripathi *et al.* (2007) reported that the storage losses for garlic under Indian conditions may be 26-40 percent for 8 months depending on the varieties and storage conditions.

These losses are consisting of physiological loss of weight (20-25%), sprouting (1 -5%) and rotting (5-10 %).

The storage losses of 15 to 40 percent have been reported from other tropical countries. The sprouting losses were higher whenever the garlic was stored at lower temperature or after onset of winter (Bahnasawy and Dabee,2006).Cantwell (2004) pointed out that garlic can be stored at room temperature (20–30 °C) for 1 or 2 months. However, the bulbs eventually loose their firmness and become spongy and discolored due to water loss. Dormancy ends quickly in garlic stored at temperatures between 5 and 18 °C.Volk *et al.* (2004) reported that the quality of garlic bulbs usually deteriorates dramatically by 6 months after harvest.

The bulb size also affects the storage of garlic. It has been reported that the weight loss and diseases are more in small size bulbs while the sprouting and rotting is more in big size bulbs. Therefore it is recommended to use medium size bulbs for storage purpose (Table. 3; Tripathi *et al*, 2007).

Table 3: Effect of different grades on storage losses after 8 months of storage

Size of bulbs	Storage losses (%)				
	Weight loss	Rot	Sprout-ing	Black mould infection	Total
AGB (>35mm)	42.07	18.15	0.7	0.2	61.12
BGB (25-35 mm)	33.25	12.69	0.2	0.2	46.34
CGB (<25mm)	28.66	11.91	0	0.2	40.77

Physiological loss of weight

Garlic is a living product and it respires continuously. The water produced during respiration evaporates slowly but continuously causing continuous loss in weight. This loss is higher at high temperature and low relative humidity conditions. The respiration rate of intact garlic bulbs is 7-13 ml CO_2/kg/hr at 20^0C which decreases with decrease in temperature and almost comes to half at 0^0C. Since almost 100 per cent garlic is stored under room temperature conditions in India, the weight loss is high and it is more particularly during the month of April to May when outside temperatures are high and relative humidity is low. It has been seen that weight loss during the 5-6 months storage is between 20-25 percent (Tripathi *et al.* ,2007).

Rot/ Decay

There are several diseases which affect garlic during storage. The causal organisms of most of these diseases are carried from field and affect the bulbs during storage. The major diseases of stored garlic are grey mould, blue mould, *Fusarium* basal rot, dry rot and bacterial rot. The most important storage diseases of garlic are grey mould and blue mould caused by *Pencilliumcorymbiferum* and other spp. The affected garlic bulbs may show little external evidence until decay is advanced. The affected bulbs become light in weight and the individual cloves become soft, spongy and powdery dry. In an advanced stage of decay, the cloves break down in a green or grey powdery mass. *Fusarium* basal rot (*Fusarium oxysporumcepae*) infects the stem plate and causes shattering of the cloves is now become major problems in those areas where garlic is repeatedly grown in the same field for years together.

The dry rot (*Botrytis allii*) and bacterial rots (*Erwinia* spp., *Pseudomonas* spp.) are comparatively less prevalent .Among the physiological disorders waxy break down of bulbs is major. It affects garlic during latter stages of growth and is often associated with periods of high temperature near harvest. Early symptoms are associated with development of small, light yellow patches on the clove flesh that darken to yellow or amber with time. Finally the clove becomes translucent, sticky and waxy, but the outer dry skins are not usually affected. Waxy breakdown is commonly found in stored garlic (Tripathi *et al.* ,2007).

Sprouting

Sprouting is not a major problem in garlic. It is very low as compared to onion. The sprouting losses in garlic are more in cold climate than warm tropical climate. Since most of the garlic is stored in India under ambient conditions, the occurrence of sprouting is recorded minimum. The internal sprouting of the cloves is common in garlic when it is stored beyond the month of October in Western Indian conditions. In most of the cases it is not visible but it increases the weight losses and affects the quality of garlic. Higher sprouting problems is noticed when garlic is stores at low temperature (0 ± 2^0C) and again kept at ambient temperature (Tripathi and Lawande, 2006). The losses due to shedding of tunics are very low in garlic as compared to onion. Generally number of tunics in garlic bulbs are restricted to 1-2 and they remain firmly attached to the bulbs.In Mexico, garlic is harvested from February to August and stored at room temperature to meet consumer demand. When the garlic sprouts, its dormancy period and effective shelf life are over, and quality decreases, leading to a decrease in its sale price (Iglesias-Enriquez and Fraga, 1998). Mann and Lewis (1956) have indicated that the dormancy period of garlic depends on temperature and time of storage

Root Growth and other disorders

High relative humidity and insufficient ventilation is the main reason cause of root growth. High Humidity and high temperature conditions, roots grew within a few days. The rooting of bulbs is generally low. The exposure of garlic to direct sun light, nutritional disorders may results in greening, rubberification, shrinkage of cloves.

Biochemical Changes during storage

Apart from the physical changes during storage, the garlic bulbs stored under different temperatures several biochemical changes take place. Storage time is a pivotal functional determinant for the garlic bioactive properties. These are responsible for flavour, taste and firmness etc of the bulbs. Kambiz Mashayekhi *et al* (2016) studied the changes in carbohydrates, enzymes, and pigments were investigated in the red garlic cv. Azarshahr bulbs in storage from harvest to sprouting under Iranian conditions. The garlic cloves were stored under dark condition at to 4 and 21°C, separately.

It was found that starch, lipase, and protease levels declined at the end of storage when clove sprouting started at both 4 and 21°C storage temperature. Starch, glucose, chlorophyll a, b, ab, and carotenoid content during the first 14 days and sucrose at 42 days showed a decreasing trend. Anthocyanin showed an increasing trend 14 and 42 days after harvesting and then decreased up to initiation of sprouting at both 4°C and 21°C storage periods.Vazquez-Barrioset et al. (2006) observed that storage of garlic at 5°C resultedin a 33% reduction in TSS.As far as allicin content is concerned,a sharp increase was observed in allicin content between 45 and 90 days after harvest when it was stored at 18°C but the sulphur (S) status in garlic bulbs was unchanged, which indicated a conversion effect of γ-glutamyl peptides to sulfoxides, a precursor compound for allicin (Nina Kacjan Marsic *et al.* , 2019).

Bahnasawy and Dabee(2006) found that antioxidant capacity of garlic cloves was maximum after 8 weeks of storage at 20 ± 2 °C, whereas for organosulfur compounds and polyphenols, the maximum content was observed between 6 and 8 weeks of storage, followed by a significant decrease after that time period (Fei *et al.*, 2015). The moisture content decreased from 60.33-63.24% before storage to 55.57-58.22% after storage period. Protein changed from 6.26-6.33% before storage to 6.62-7.18% after storage period. Fiber percentage ranged from 2.12-2.15% before storage to 2.16-2.22% after storage period. Carbohydrates increased from 26.30-27.37% before storage to 30.74-33.36% after storage period, depending on storage system, package type and bulb size (Bahnasawy and Dabee, 2006).

Factors effecting storage losses and their Management

There are several factors which are associated with storage losses in garlic. Generally management of storage losses is initiated after the harvest of the crops. There are many pre harvest aspects which affects the storage of garlic. These includes genetic makeup of cultivars, type of manure and fertilizer and their time of application and quality ,quantity, method and time of application of water, pre harvest treatments, harvesting time etc. Post harvest factors include field curing, drying, store environment, storage structures etc.

Genotypes

More than 100 varieties and several hundred landraces of garlic are grown throughout the world. They are broadly classified into soft neck and hard neck (also known as top set) varieties. Hard neck varieties (*Allium sativum* var. *ophioscorodon*) bolt during late spring/early summer, producing a tall, flower stalk or scape. There is considerable variability in the size and number of bulbils produced by hard neck garlic (Table 4). Bulbils may be used as planting stock but require 2 or more years of growth to develop into marketable bulbs.In hard neck garlic, there are a number of subgroups including Porcelain, Rocambole, Purple Stripe, Marbled Purple Stripe, Glazed Purple Stripe, Asiatic, Turban and Creole. Each of these subgroups has general characteristics that make them better suited for certain climates, have favourable growth tendencies, or exhibit unique flavor profiles.

Hard neck garlic may be purple, purple striped, or white and is represented by varieties such as Roja, German Red, Valencia, Continental, and Creole. Soft neck varieties (*A. sativum var. sativum*) do not produces a scape and do not produce bulbils, except in times of stress. A general rule of thumb is that hard neck varieties are more winter hardy, produce larger cloves but have a shorter storage life than soft neck varieties. Most of tropical counties grow soft neck varieties of garlic. The storage conditions prevailing the tropical conditions have much influence on the storage life of the garlic. Taicangbaipi, Ershuizao, Hongqixing, and Single-clove, Ershuizao and Hongqixing are some varieties of garlic in China. Tsedey and Bishoftu Netchare are most common varieties in Ethiopia. In Bogor (Indonesia), a local garlic variety, i.e. Lumbu Kuning is grown which has medium storage life. Two garlic varieties dominate in the US are California White and California Early. Garlic cvs . Cateto Roxo Mineiro 2 and the Cateto Roxo Mineiro 1 are grown in Brazil. Balady and Chinese-Sids40 are the main garlic cultivars grown in Egypt.

In Bangladesh new improved varieties of garlic, are BARI Rashun-1, BARI Rashun-2, BAU Rashun-, and BAU Rashun-2. Three commercial cultivars i.e. Garcua, Gardacho, and Gardos are grown in Turkiye (Nina Kacjan Marsic*et al.*, 2019). The storage life of these cultivars is different. It may ranges from 2 to 6 months. The total solid content, pungency content and chemical composition of the genotype also effected the storage period. Tripathi *et al* (2021) found that the smaller clove varieties having higher solid content perform better than varieties having lower sold content.

Table 4: Comparison of morphological traits of the three forms of garlic(Engeland, 1992)

Trait	***Allium longicuspis***	***Allium sativum var. aphioscorodon***	***Allium sativum var. sativum***
Bolting/ Non bolting	Bolting	Bolting	Non bolting
Anthers	Exserted	Deformed	Non Exserted
Bulb colour	Blotchy or stripped purple	Purple./ porcelain	White
Bulb Layers	1-2	2	4
Clove numbers	8	8	15
Clove colour	Brown	Brown	White
Maturity	Late	Late	Early
Scape	Rocambole: tightly coiled Continental: loose coil	Rocambole: tightly coiled Continental: loose coil	NA
Bulb scales	-	-	Artichoke: Coarse Silver skin: Fine and smooth

The cultivars vary in their storability because of their inherent duration of dormancy. This is measured by the time to sprout either in storage or after planting in the field. It is considered that the purple coloured varieties have better shelf life than white coloured varieties. However, very little information is available on storability of garlic varieties under different tropical regions.

The type and quantity of fertilizers and manures exercise great impact on the storage life of garlic. The recommended dose for garlic is 100 kg Nitrogen, 50 kg phosphorous and 50 kg potassium. The half of the nitrogen and full quantity of potassium and phosphorus should be applied at the time of planting while the remaining amount of nitrogen should be applied in equal quantity at 30 and 60 days after planting. The late application of nitrogen adversely affects the storage life of bulbs. Further the high nitrogen application leads to thick neck bulbs that are more prone to entry of pathogens. The type of fertilizers also have influence the storability of garlic. The ammonium fertilizers have been found better than nitrate fertilizer for storability. The applications of sulphur have been found helpful in shelf life of garlic. The organic fertilizer and green manure also found enhancing the storability of garlic.

The most important active compound in garlic is alliin. Sulfur (S) fertilization was shown to significantly increase the alliin concentration in garlic cloves, while high nitrogen (N) levels had an adverse effect. The effect of graded N and S application on the storage life of garlic has been paid little attention so far. S fertilization increased the alliin concentration by a factor of 2.3 from 11.4 mg/g−1 in the control treatment to 26.6 mg/g−1 dry weight at the highest S level of 45 kg/ha−1 after 83 days of storage. N fertilization decreased by a trend of the alliin content. Fertilizer rates had only a minor influence on water losses from bulbs at short-term storage. After 83 days of storage, water losses were by trend lower at higher S levels, and this relationship proved to be significant when no N was applied. Best quality in terms of high alliin contents and longer storage life was obtained by the application of 30 kg/ ha (Elke Bloem*et al,* 2011). Nitrogen and Sulphur fertilization significantly increased the allicin content of Gardos bulbs (Nina Kacjan Marsic *et al.* , 2019).

Sulphur fertilization significantly increased tyeild and quality of garlic (Choudhary *et al* .,2017). Foliar application of potassium silicate was found effective in increasing storage life in garlic. The highest plant length, number of leaves, fresh, dry weight\plant, neck diameter, bulb diameter and chlorophyll content of garlic were achieved from foliar application of potassium silicate at the 4000ppm after 120 days from planting compared to the control. The weight loss and shrinking percentages of the bulbs after 7 months of the storage were the least with the foliar application of potassium silicate at 8000ppm with chitosan at 200ppm at the room temperature conditions (Shadia Ismail *et al.,* 2019).In an organic cultivation trials, the storage life was found better than the garlic bulb produced with inorganic fertilizer (Tripathi *et al.*,2007).

Water management

The quality of water and time and method of irrigation greatly influence the storability of garlic. It has been noticed that if the water quality is not god the decay problem is enhanced in the storage. The water with high content of contaminants from the cities used for irrigation of garlic particularly during the maturity period increases rotting as compared to the underground water. The time of irrigation also effects storage. The irrigation should not be applied after the crop has reached to maturity. Generally it is recommended that irrigation should be stopped 15 days before harvest of the crop (Tripathi *et al*, 2002).The studies on the methods of irrigation conducted at Rajgurunagar(Pune) in western India revealed that storage losses were lower in the garlic with drip irrigation with 75 % to 100 % PE as compared to surface irrigation.

This was probably due to the optimum quantity of water applied during the maturity of the bulbs. Further the soil remains soft in drip irrigation method which facilitates easy harvesting of the bulbs and reduces the injuries to the bulbs during harvesting. Irrigation before harvest to facilitate easy harvest often enhance rotting losses. Therefore harvesting should be done at proper moisture level (Sankar *et al.*, 2007, Tripathi *et al.* 2017). Field experiments carried out at Navsari (Gujarat, India) during winter season revealed that highest percentage of total weight loss was recorded at 120 days after storage irrespective of different treatments which indicates that garlic bulb can be stored up to 90 days after harvest without much reduction in weight.

The maximum and minimum percentage of total weight loss was recorded under treatment of surface method of irrigation with 1.0 IW/CPE ratio (I3) and mini sprinkler method of irrigation with 0.6 IW/CPE ratio (I1) respectively at all the stages during both the years. Incase of weed management practices the highest percentage of weight loss was recorded with the treatment pendimethalin at 0.75 kg/ha as pre-emergence coupled with one hand wedding at 50 days after sowing (W4) Significantly the lowest percentage of weight loss was observed in treatment of unweeded control (W1) at all the stages during both the years of experimentation (Thanki and Patel, 2010)

Effect of pre-harvest treatments

The pre-harvest application of some chemicals have been found helpful in reducing the storage losses. Application of carbedazim @2g/l one week prior to harvesting has been found effective in reducing the storage losses due to decay. Pre harvest spray of carbendazim was found to reduce field load of disease causing bacteria and fungus before garlic is loaded in the storage structures (NHRDF, 1997). The use of maleic hydrazide (1,2-dihydropyridazine-3,6-dione) [MH] , a plant growth regulator, has been widespread in various garlic growing regions of the world. The sprouting can be prevented by pre harvest application of growth regulator like Maleic hydrazide@ 1500 to 3000 ppm before neck fall when the leaves are green (NHRDF,1997; Ratanamarno and Supa,2015)). Maleic hydrazide (MH) had been used for sprout inhibition but at present it is prohibited due to health hazards. Ratanamarno and Supa (2015) reported that pre-harvest treatment using 2500 ppm protocatechuic acid (PCA), 25 ppm abscisic acid (ABA) as spray to leaves three weeks before harvest and storage at ambient gave the longest storage life of 300 days, which was comparable with 2,500 ppm MH.

This result indicates the potential of PCA and ABA as MH substitute. Pre-storage coating treatment of peeled and un-peeled garlic cloves with either garlic and onion oils, potassium sorbate and sodium benzoate maintained a protective effect against black mould infection during storage for four months. The pre-storage application of essential oils indicated a superior inhibitory effect on black mould incidence in garlic cloves when compared with the food preservatives. The study indicated that garlic and onion oils, potassium sorbate and sodium benzoate could be used as antifungal non-hazardous treatments and could be safely used for fresh products in Egypt (El-Mougy *et al.* 2007). Sharma *et al* (2010) study the storage life of garlic cultivar 'GHC 1', including treatments comprised knotting tops one month prior to harvesting (indigenous practice) and general practice of no knotting of tops, followed by application of iron sulphate, borax and maleic hydrazide @ 2000 ppm (check) each 2 weeks prior to harvesting of bulbs.

The indigenous practice of hanging bulbs in storage significantly resulted in minimum loss of weight and incidence of sprouting, rotting and drying of bulbs compared 25% over no chemical application and also recorded low incidence of sprouting, rotting and drying of bulbs. The use of borax could be beneficial for minimizing the storage losses forlarge-scale storage of garlic bulbs, while indigenous practice could be a suitable preposition for small-scale storage compared to no chemical spray by selling the bulbs during storage.

Harvesting time and method

The change of leaf colour is the sign of maturity in garlic. The stage of maturity of cloves at harvest has significant influence on dormancy. As the bulbs reach maturity, the plants cease to produce new leaves and senescence starts. The tops just above the neck of the bulbs weaken and bend down still remaining green. Further, there is development of bulbils in the pseudostem just above the ground. This is also an indication of maturity in tropical type of garlic. Bulbs continue to increase in size and weight for sometime after softening of the neck and falling over.

This increase is due to continued accumulation of dry matter in the bulb. Bulbs harvested after neck fall have been reported to take less time for drying and curing and shown have marked reduction in storage rot. Garlic harvested when the leaves are still green, require more time to sprout than mature cloves harvested when the foliage has dried. It has also been reported that harvesting of garlic bulbs before the tops have fallen over indicating full maturity, results in poor storage whereas delayed harvesting results in splitting of bulbs and re-sprouting of bulbs (NHRDF, 1997, Tripathi and Lawande ,2004).

Harvesting is done manually by uprooting. Some time the hand hoe is used in hard soil for harvesting. Harvesting with hand hoe damages lot of bulbs. These bulbs get disease infection and exhibits more losses in storage. Therefore care should be taken to harvest garlic in a optimum moisture level and optimum stage of ripening to minimize the storage losses. Generally garlic is stored after making bunches of 20-25 bulbs by tying their leaves.

Effect of removal of tops

Garlic should be stored with leaves for better storage. These bulbs are to be hung by their tops or stored in circular heaps. Hanging of garlic bundles along with leaves is a indigenous practice is adopted for garlic storage in most of the garlic growing areas of the world particularly for domestic consumption and seed purpose. However the presence of leaves for marketing and large scale storage is undesirables as it affects the grading, packing marketing of the bulbs. The topping of garlic is done after curing or sometime after on farm storage (NHRDF, 1997, Tripathi and Lawande, 2004). The studies conducted at NRC Onion and garlic revealed that cutting of leaves exhibits higher weight loss and other storage losses as compared to the garlic stored with leaves. The minimum loss (11.52%) in weight was observed in bulbs stored by hanging with tops (Mahajan, *et. al.,* 2005). The only constraint is that the untopped garlic bulbs require larger area as compared to bulbs without leaves.

Field curing and shade drying

After harvesting the bulbs are is left in the field for 3-4 days for removal of excess surface moisture and drying of leaves. This allows the formation of strong outer protective scales and hardening of neck. Garlic bulbs, after harvest, are cured naturally in the field by windrowing in such a way that the bulbs of one row are protected from the sun by the foliage of the adjacent row. This is practiced in places where the temperature is mild. Exposure of bulbs to the sun for longer period may cause damage to the skin making them more vulnerable to storage rot. Normally, it takes about a week for during of foliage and outer scales. After field curing, the bulbs are cured in a ventilated shed for 7 to 15 days either with tops or after cutting the tops leaving about 2.5 cm neck intact. The roots are removed completely. Artificial curing can be done by blowing hot air at 27 to 35°C through the curing room. It takes about 48 hours for completion of the process when the relative humidity is between 60 to 75% (NHRDF, 1997, Tripathi and Lawande ,2004).

Curing

The purpose of the curing is to store longer duration and prevent diseases/pests, hence prolonging the shelf life After harvesting, the plants should be moved from the field into a dark, dry, well-ventilated area for drying and curing of the bulbs. Bulbs should be moved out of the sunshine as quickly as possible after digging. Do not dry by laying the plants in the sunshine. Tops and roots can be removed after several weeks when drying and curing are complete. The top of a cured bulb is topped at about 2.5cm above the bulb. Once pulled, bulbs can be gathered in the field and left to field cure if there is no chance of rain. If rain is expected, plants should be collected and cured in a dark, dry, well-ventilated covered area. Plants can either be spread flat on benches, racks, slotted trays, or wire screens or by hanging bunches of 10 to 12 bulbs tied with string. Curing or drying of the bulbs for 10 to 14 days is necessary if harvested with some leaves still green (NHRDF, 1997, Tripathi and Lawande ,2004). In Hawaii , If harvesting done after the leaves (tops) have dried in the field, then minimal curing is necessary. When the tops (green leaves) have dried, the roots and the tops are cut off, leaving about one inch (25 mm) above the bulb.

Post-harvest treatment

There are some post harvest treatments which have been found successful in reducing the losses during storage.

Effect of sulfur fumigation

Sulphur fumigation improves the storage life of garlic. The sulphur fumigation was found to decrease the black mould infection in garlic bulbs. The studies conducted at NRC Onion and Garlic revealed that bulbs of

Garlic cv.G-41 when fumigated with 50g sulphur /m3 for more than one hour significantly reduced the soft rot and black mould infection. The sulphur fumigation did not show any effect on weight loss and sprouting. Fumigation should be done after loading of garlic in storage structure (Tripathi *et al*, 2007).

Effect of gamma irradiation

Several workers have attempted irradiation of garlic with gamma rays for controlling sprouting. The dose varies from 50 Gy to 250 Gy. The radiation treatment given to bulbs within 8 weeks of harvest (before sprouting) can inhibit sprouting effectively, reduce weight loss and prolong storage life for about one year (Bongirwar and Shirsat, 2000). The studies conducted at Pune (India) revealed that when well-cured and dried bulbs of garlic irradiated with 75 Gy dose of cobalt-60 package irradiator and stored at ambient condition from May to January, recorded no sprouting even up to 230 days. Under cold storage there was no sprouting in irradiated as well as un-irradiated bulbs. However, when the bulbs were taken out of cold storage un-irradiated bulbs sprouted heavily and it was 74.54 % (Tripathi *et al.*,2007). Ibrahim *et al* (1971) found that Gamma irradiation (12 Krad) was more effective than preharvest application of maleic hydrazide(2500 ppm) in controlling sprouting and extending the storage life of garlic bulbs.

Gamma irradiation decreased the length and thickness of internal sprouts and entirely prevented chlorophyll formation insprouts; it decreased external discoloration and disease to a greater extent than did maleic hydrazide treatment. Both treated and untreated bulbs held in cold storage (0°C; 90-95% RH) showed a longer storage life than did those held in common storage (15-30°C; 50-75% RH). Gamma irradiation, maleichydrazide treatment, and cold storage reduced weight loss and delayed emaciation. Curzio *et al.*(1986) investigated several chemical parameters in 'red' variety garlic irradiated to inhibit sprouting, with doses of 30 Gy and kept under warehouse conditions. It was found that the irradiated garlic showed a significant increase in ascorbic acid content during storage but there was no change in dry matter content compared with non-irradiated garlic**.** The irradiated garlic had a higher index of flavour, measured as enzymatic pyruvate, a higher acidity and a lower content of water-soluble carbohydrates compared with non-irradiated garlic at 270 days of storage. These studies showed that the irradiation of garlic bulbs is was found beneficial for prolonging storage life.

Storage

Storage method

Traditional method of hanging bundled garlic

Hanging garlic bunches under ceilings of houses is also common practice to maintain planting material for next season in all garlic growing regions. Generally 10 -15 garlic are tied in a bundle and their leaves kneaded together. In India, the hanging of garlic in most common practice to store the garlic for domestic consumption and seed purpose. The storage losses in this practice are low and garlic can be stored up to next season (NHRDF, 1997, Tripathi and Lawande ,2004). Sharma *et al* (2010) found that indigenous practice of hanging bulbs in storage significantly resulted in minimum loss of weight and incidence of sprouting, rotting and drying of bulbs. Hanging garlic bunches under ceilings of houses is also common practice to maintain planting material for next season in Ethiopia. The disadvantage of this method is that very limited quantity of garlic can be stored.

Storage in Heaps

The another method used in Indian subcontinent is to stored garlic in heaps of various size along with leaves kneaded togather. Generally the size of head may be different as per requirement. NRC Onion and Garlic ,Pune (india) modified these heap size and found that circular heaps made on ventilated floor in s bottom ventilated structure most efficient in reduction of storage losses. The bet diameter of these circulars heap shoud be around 1 meter and height is around 120 cm. The garlic tied in bundles along with leaves and arranged in these heaps (Tripathi and Lawande , 2004; Tripathi *et al.* 2009). The disadvantage of this method is it can be adopted at only at on farm storage as it is difficult to transport and pack garlic with leaves.

Thus the garlic leaves are cut after proper field and shade curing. The stem of almost 2.5 cm should be kept with the garlic bulbs. It has been found the neck length of 2.5 cm found to increase the storage life and reduce the incidence of disease infection as compared to no neck. (Tripathi *et al*, 2007). After removal of leaves the garlic bubs are packed in different types of bags and market and storage.

Packing

Packing is a vital component of post harvest management to assemble the produce in convenient units and to protect it from deterioration during handling and marketing. Adequate packaging protects the produce from physiological, pathological and physical deterioration in the marketing channels and retains their consumer attractiveness. The garlic is generally packed in Hessian cloth bags of various sizes for marketing. Now the use of netlon bag, Card board boxes, crates and consumers pack (1 to 5 kg) is also getting popularity. Tripathi and Lawande (2009) observed the physiological loss in weight loss of the garlic cv. G41 in cold storage for the hessian cloth bag and netlon bag was lower than plastic crates . In Ethiopia, bulbs are transported and stored in 25, 50, 120kg bags in dry stores by vendors. Storage life under appropriate conditions could be 5 –8 months at room temperature for seed purpose depending on the variety. El-Sayed G. Khater *et al* (2006) found that garlic stored in plastic bags recorded the highest accumulated weight loss (14.00%) when stored at ventilated storage system.

Storage environment

The storage of garlic besides, genotypic factors, largely depend on conditions in the storage structures. There are two distinct temperature regimes where losses are minimum. One is high temperature regime, where storage temperature is 25-30^{0}C and another is low temperature regime, where temperature is augmented maintained 0 to 2^{0}C. Best results under both the temperature regimes are obtained when humidity is maintained at 65 to 70 %. The storage losses in high temperature conditions (25-30^{0}C) are high (30-35%) but storage cost is low. While in low temperature conditions (0-2^{0}C) or cold storage conditions losses are minimum (0.5%) and storage period is longer. However, storage cost is high. Higher temperature (more than 30^{0}C) in ambient storage structures lead to higher weight loss while lower temperatures (less than 10^{0}C) enhance sprouting losses. Higher humidity (more than 70$^{\%}$) coupled with higher temperature enhance storage diseases, while lower humidity enhance weight loss .

Ambient temperature storage

Tripathi *et al.* (2009) evaluated four different types of storage structures for storage of garlic under Western Indian conditions of from April to November. Among the various storage structures evaluated for garlic storage, the lowest losses (25.39%) were recorded in modified top and bottom ventilated double row storage structure. This was followed by modified bottom ventilated double now structure (27.43%). The losses to due soft root infection was lowest (11.49%) in modified bottom ventilated storage structure. Similarly the black mould infection was significantly lower in ventilated storage structure than traditional non-ventilated structure. The discolouration of bulbs from white to yellow, which was measured as per hedonic scale, was highest in traditional non-ventilated storage structure and it was lowest in top and bottom ventilated double row storage structure.

The visual quality of the bulbs in 10 - point scale was highest (6.25) in top and bottom ventilated double row structure. In Hawaii, the dried bulbs are held in a cool, dry, and well-ventilated area in paper or mesh bags, and normally remain in good condition for one to two months at 20-30^o C. Garlic odor can be readily transferred to other fruit, vegetables, and other food products; hence, it needs to be stored separately. The symptoms of the end of storage life include clove shriveling due to water loss, soft and spongy texture, and in some cases, a waxy appearance. A waxy appearance is common when the preharvest weather is hot during harvest, bulbs are exposed to the sun during curing in the field or after harvest, and there is poor ventilation during curing and storage. The waxy cloves are yellow amber and later become translucent, waxy, and sticky, with the scales showing no symptoms. If the storage area is not dry and has a high relative humidity, a number of diseases can occur including Blue mold, Black mold and Grey mold.

El-Sayed G. Khater *et al* (2006) found that under traditional storage system recorded was 36.89 % compared with 12.33 % for the garlic stored in ventilated systems. The garlic stored in plastic bags recorded the highest accumulated weight loss (14.00%) when stored at ventilated storage system while the same package recorded the lowest weight losses (9.75%) when stored in the cold storage. The highest value of accumulated moisture loss (7.30%) was recorded by the garlic bulbs stored in clothes bags, while the lowest value of accumulated moisture loss (5.18%) was recorded for the garlic stored in plastic bags. Sprouting percent ranged from 14.00 to 21.79 % where the cold storage system recorded the lowest percentage, and the traditional system recorded the highest sprouting. Sprouting ranged from 17.53 to 24.86 % at ventilated system storage. The highest value of empty blubs percentage of garlic (11.03 %) was recorded by the garlic bulbs stored in plastic bags under ventilated storage system, while the lowest value of empty blubs percentage of garlic (2.15 %) was recorded for the garlic stored in plastic bags under cold storage system. Lawande and Tripathi (2019) and Tripathi and Lawande (2019) concluded that among various storages structures tested, structure with bottom and side ventilation of 10, 25, and 50 tons capacity are recommended. The higher temperature controlled storage (25^{o}C +- 5^{o}C) and 65 +- 5% relative humidity may be good option for tropical region. Although, there will be 15-20% storage losses for a period of 4-5 months. This storage with force ventilation and moisture control system may be a cheaper option. This may be suitable for both on farm and community storage. There is need to design and evaluate force ventilated controlled atmosphere storage structures.

Low temperature Storage

Postharvest life of garlic bulbs can be considerably extended up to 9 months by storage at about 32° F (0° C) and 60-70% relative humidity. Tripathi and Lawande (2007) studied effect of gamma -irradiation and cold storage on storage losses in garlic. It was found that cold storage of garlic reduced physiological weight loss and infection due to diseases. These losses were much less than ambient stored garlic even after 5 months of storage. Unirradiated cold stored garlic showed rapid sprouting during post cold storage period but this low temperature induced sprouting was not noticed in gamma irradiated cold stored garlic. Overall, the gamma irradiation followed by cold storage minimized the storage losses by 15 % to 20 % and increased the shelf life of garlic. The highest total losses (77.4%) were recorded in unirradiated cold stored garlic bulbs after 230 days of storage. This treatment was statistically at par with the unirradiated ambient stored bulbs (74.5%).

The lowest storage losses were found in gamma irradiated cold stored bulbs, which were 54.8 %, and this treatment was significantly lower than all other treatments. Storage losses in ambient stored gamma irradiated bulbs were 64.8 % and this treatment was statistically better than unirradiated ambient and unirradiated cold stored bulbs. Volk *et al.* (2004) reported that the response to cold-storage conditions was cultivar dependent. Several chemical parameters were investigated in 'red' variety garlic irradiated to inhibit sprouting, with doses of 30 Gy and kept under warehouse conditions. The studies were conducted between 210 and 270 days post harvest (critical marketing periods) when this variety was not normally available for raw consumption. It was found that, during storage, the irradiated garlic showed a significant increase in ascorbic acid content but no change in dry matter content compared with non-irradiated garlic.

Compared with non-irradiated garlic, at 270 days' storage, the irradiated garlic had a higher index of flavour, measured as enzymatic pyruvate, a higher acidity and a lower content of water-soluble carbohydrates. From these observations, the irradiated garlic should be suitable for prolonged storage with the object of marketing it during critical periods (Curzio *et al*., 1986). Purwanto *et al.* (2019) studied the effect of storage temperature on the quality of garlic during storage under Bogor conditions in local garlic variety, i.e. Lumbu Kuning . The bulbs were stored at different temperature storage conditions, i.e. 0°C; 7°C (RH 50-70%, darkness), and a room temperature (29-31°C, RH 70-80%) for 6 months. The results revealed that highest weight loss was found from the bulbs stored at 7°C (25.08%), followed those stored at the room temperature (18.76%) and 0°C (10.47%). The highest sprouting percentage occurred in those stored at 7°C (25.16%). El-Sayed G. Khater *et al* (2022) studied the effect of storage system (cold, ventilated and traditional) and package type on the quality of garlic during storage under Egyptian condition.

The results indicated that, the total accumulated weight loss increases with increasing the storage period. The traditional storage system recorded was 36.89 % compared with 11.47 and 12.33 % for the garlic stored in the cold and ventilated systems. The garlic stored in plastic bags recorded the highest accumulated weight loss (14.00%) when stored at ventilated storage system while the same package recorded the lowest weight losses (9.75%) when stored in the cold storage. The highest value of accumulated moisture loss (7.30%) was recorded by the garlic bulbs stored in clothes bags, while the lowest value of accumulated moisture loss (5.18%) was recorded for the garlic stored in plastic bags.

Sprouting percent ranged from 14.00 to 21.79 % where the cold storage system recorded the lowest percentage, and the traditional system recorded the highest sprouting. Sprouting ranged from 17.53 to 24.86 % at ventilated system storage. The highest value of empty blubs percentage of garlic (11.03 %) was recorded by the garlic bulbs stored in plastic bags under ventilated storage system, while the lowest value of empty blubs percentage of garlic (2.15 %) was recorded for the garlic stored in plastic bags under cold storage system. In Ethiopia, it was found that storage at °C and 60% relative humidity can prolonged storage period. The higher temperature shortened the storage life. Adequate air flow and proper storage containers are important to remove transpired heat and moisture. Otherwise, higher relative humidity provides suitable conditions for development of mold and root growth,

In the Bajio region of Mexico, six batches of 360 bulbs of garlic cv. Perla were stored for 190 days at 0 °C, 0 °C and 70% relative humidity (RH), 5, 20, 30 °C, and at room temperature (RT) (17.7 ± 7 °C). The weight loss and internal sprouting index had a negative correlation on the subjective firmness, penetration resistance, and hue of the cloves. Storage at 5 °C, 20 °C, and RT induced sprouting, and subsequent growth had an effect on a loss of firmness and color. Complete sprouting (>100%) induced a weight loss of 9–11% at these temperatures. In order to maintain an adequate safety margin for marketing, we propose an internal sprouting index of 50% to determining the effective shelf life of garlic cv. 'Perla'. In accordance with this criterion and in conditions studying, shelf life at 0 °C was 155 days; at 5 °C and RT it was 80 days; and at 20 °C it was 60 days.

These results lead us to conclude that it is possible to estimate the shelf life of garlic using the internal sprouting index (Vázquez-Barrios *et al.*, 2006). Bahnasawy and Dabee (2006) studied the effect of storage system (cold, ventilated and traditional) and package type on the quality of garlic during storage. The results indicated that, the total accumulated weight loss increases with increasing the storage period. Storage system had a great effect on the losses, where, the traditional storage system recorded was 36.89 % compared with 11.47 and 12.33 % for the garlic stored in the cold and ventilated systems. The garlic stored in plastic bags recorded the highest accumulated weight loss (14.00%) when stored at ventilated storage system while the same package recorded the lowest weight losses (9.75%) when stored in the cold storage. The highest value of accumulated moisture loss (7.30%) was recorded by the garlic bulbs stored in clothes bags, while the lowest value of accumulated moisture loss (5.18%) was recorded for the garlic stored in plastic bags. Sprouting percent ranged from 14.00 to 21.79 % where the cold storage system recorded the lowest percentage, and the traditional system recorded the highest sprouting. Sprouting ranged from 17.53 to 24.86 % at ventilated system storage.

The highest value of empty blubs percentage of garlic (11.03 %) was recorded by the garlic bulbs stored in plastic bags under ventilated storage system, while the lowest value of empty blubs percentage of garlic (2.15 %) was recorded for the garlic stored in plastic bags under cold storage system. The highest value of accumulated moisture loss (7.30%) was recorded by the garlic bulbs stored in clothes bags, while the lowest value of accumulated moisture loss (5.18%) was recorded for the garlic stored in plastic bags. • The total accumulated weight loss recorded was 36.89 % for the garlic stored traditionally, compared with 11.47 and 12.33 % for the garlic stored in the cold and ventilated systems. The garlic stored in plastic bags recorded the highest accumulated weight loss (14.00%) when stored at ventilated storage system while the same package recorded the lowest weight losses (9.75%) when stored in the cold storage.

Sprouting percent ranged from 14.00 to 21.79 % where the cold storage system recorded the lowest percentage, and the traditional system recorded the highest sprouting. Sprouting ranged from 17.53 to 24.86 % at ventilated system storage. • The highest value of empty blubs percentage of garlic (11.03 %) was recorded by the garlic bulbs stored in plastic bags under ventilated storage system, while the lowest value of empty blubs percentage of garlic (2.15 %) was recorded for the garlic stored in plastic bags under cold storage system (Ibrahim *et al.*, 2018). All these studies suggested that post-harvest life of garlic bulbs can be considerably extended up to 9 months by storage at about 32° F (0° C) and 60-70% relative humidity with good ventilation in vented bins or mesh bags. There are approved chemicals or gamma irradiation may be used to inhibit sprouting.

The storage losses in garlic is tropical regions are high. Lot of attempts have been made to reduce the losses. Several research findings have shown that the losses cab be reduced. But the storage conditions, climatic conditions, cost of storage, poor adoption of the research findings are the main impediments. There is still needs to develop the cost effective technologies for the garlic storage in tropics.

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