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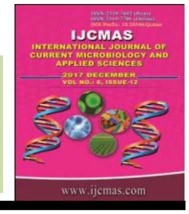

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Effect of Withholding Irrigation and Different Harvesting Times on Post-Harvest Quality of Garlic (*Allium sativum* L.) During Storage

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A B S T R A C T

The present investigation entitled "effect of withholding irrigation and different harvesting times on post-harvest quality of garlic (*Allium sativum* L.) during 240 days of storage" was carried out at Research Farm of Department of Vegetable Science and in Post-harvest Laboratory of the Department of Horticulture, CCS Haryana Agricultural University, Hisar, Haryana in 2013-2014. Five levels of withholding irrigation, *i.e*., 35, 28, 21, 14 and 7 days before harvesting and five levels of harvesting time *viz*., 150, 157, 164, 171 and 178 days after planting were applied. The Randomized Block Design was used for field studies and Completely Randomized Design for laboratory studies with four replications. The influence of these treatments were recorded on quality parameters *viz*., total soluble solids and sulphur content in garlic at 30 days interval. Results revealed that both quality parameters increased with the decrease in days to withholding irrigation and with delay in harvesting up to 171 days after planting. Both quality parameters were found maximum with treatments where irrigation was withheld 7 days before harvesting and in treatment where harvesting was done 171 days after planting. Regarding storage period, both TSS and sulphur content increased during earlier part of the storage, *i.e*., from beginning to 150 days of storage, but thereafter, it decreased up to the end of storage (240 days).

Introduction

Garlic (*Allium sativum* L., 2n= 16), belongs to Alliaceae family, is one of the important bulb crop which is widely cultivated throughout the country (Dayi, 2008). This aromatic herbaceous plant originated in Central Asia and later spread to Mediterranean region (Simon, 2001; Kigori *et al*., 2005). Due to multiple uses and export potential, the cultivation of garlic has been encouraged in India on commercial scale. It possesses anti carcinogenic, microbial and insecticidal properties. The pungency of garlic is due to presence of sulphur containing compound diallyl disulphide and because of its pungent flavor, it is used mainly as a spice, seasoning and flavoring for foodstuff involving both green tops and bulbs. It is grown in many countries, like Egypt, United States of America, China, India, Korea, Thailand, France, Spain, *etc*. The area and production of garlic in India during 2015-2016 was 280.95 thousand hectares and 1617.34 thousand MT, respectively with productivity of 5.76 tonnes/ hectares (Anonymous, 2015). It is grown on large scale in Madhya Pradesh, Gujarat, Orissa, Rajasthan, Karnataka, Tamil Nadu, Maharashtra, Bihar, *etc*. Madhya Pradesh is the leading state since it is contributing 29% of the total production of garlic in India.

Garlic possesses a wide range of variability in bulb and yield traits as well as storability in spite of being vegetatively propagated crop. It is highly susceptible to agro-techniques and environmental conditions. Farmers cultivate this crop under irrigated conditions mainly from October to March, which has cool-dry conditions that favour growth and development of garlic crop. Irrigation requirement of garlic was studied by Sadaria *et al.*, (1997). Being solvent, water is pre-requisite to successful garlic production (Michael, 1999) in relation to bulb size, weight and quality (Hanelt, 1990). The optimum soil moisture for emergence was 80-100% of field capacity. However, keeping quality was poorer than that of plant grown at a lesser soil moisture, because of the large cells and thinner cuticle, which led to higher transpiration. Because of fibrous and shallow root system, it requires adequate moisture for proper establishment, growth, development and yield and quality of bulbs (Karaye and Yakubu, 2007). Garlic tolerates neither excess nor scarcity of water as both could decrease yield (Buwalda, 1987). Efficient use of water is vital for economic production since scarcity and excess of irrigation reduce yield, storability and quality of garlic (Chuman and Maurya, 1986). Quality of garlic bulbs can be affected by mineral nutrition, fluctuation in harvesting time, irrigation schedule, methods of harvesting, rainfall, *etc*. (Chung, 1989). In Haryana, garlic is gaining much popularity during recent years on accounts of higher returns, longer storage and least problems in its cultivation. Here, it is planted in September-October and harvested in April-May. Physiological loss in weight (PLW), sprouting and rotting are the main causes of losses during storage, and adverse weather conditions affect its quality and storability. Excess moisture at harvesting causes fast deterioration like rotting, early sprouting, *etc.* during storage. Later the garlic bulbs are harvested more will be the reduction of moisture in bulbs (Bayat *et al.,* 2010). Both, water and nutrient management for onion production have a significant effect on postharvest behaviour of the produce. These pre-harvest inputs influence the storage behaviour of onion bulbs directly or indirectly (Komochi, 1990). The bulbs grown under low soil moisture regimes are usually smaller and tend to lose more moisture and dry earlier during storage (Narang and Dastane, 1972). Similarly, small-sized bulbs with higher surface area lose more moisture since water vapour losses occur lengthwise from the side of onion, thus, dry earlier than large-sized bulbs. Storage losses in onion could be as high as 66%, and many factors, such as cultivars, bulb maturity, moisture content of the bulb, temperature, relative humidity, *etc*. are associated with spoilage of onion during storage (Rabbani *et al.,* 1986). In contrary, Suojala *et al.,* (1998) reported that irrigation had only a minor effect on the storage performance and shelf life of onion. Therefore, to ensure better quality bulbs, the study was undertaken to find the effect of withholding irrigation and different harvesting times on post-harvest quality of garlic.

Materials and Methods

The experiment was carried out during *rabi* season in 2013-14 at Research Farm of the Department of Vegetable Science and in Post-harvest Laboratory of the Department of Horticulture, CCS Haryana Agricultural University, Hisar, Haryana. The Hisar is situated in region that has semiarid climate with hot and dry winds during summer and dry severe cold in winter. The maximum temperature was ranged between 19.5 to 41.0 °C, while the minimum was ranged between

5.6 to 26.9 **°C** during complete experimental period**.** The soil of the experimental field was sandy loam with slightly high pH and EC of 8.2 and 0.39 dS/m, respectively. The soil was medium in nitrogen, low in phosphorus and high in available potassium (129, 21 and 291.61 kg/ ha, respectively). The planting of garlic cv. HG-17 was done on October 25, 2013. For field and laboratory studies, the experiment was laid out in Randomized Block Design and Completely Randomized Design, respectively with four replications. Five levels of withholding irrigation, *i.e*., 35, 28, 21, 14 and 7 days before harvesting and five levels of harvesting time *viz*., 150, 157, 164, 171 and 178 days after planting were applied in well ploughed beds of 4 × 4 m^2 size with a planting distance 15 cm × 10 cm. A basal dose of well rotten farmyard manures @ 15 tonnes/ha incorporated in the soil before one month of planting. In addition to this, a uniform dose of 80 Kg N through urea, 50 kg P_2O_5 through SSP (single super phosphate) and 25 kg K_2O through MOP (muriate of potash) per hectare was applied for better growth and proper nutrition of garlic. The half amount of nitrogen with full doses of P_2O_5 and K_2O were applied at the time of planting, while remaining nitrogen was top dressed at 30 day after planting. Irrigation was applied at 10 to 15 days interval but withholding of irrigation was done as per the treatments. First hoeing was given 20 days after planting. Two more hoeing were given at 40 and 65 days after planting to control the weeds. The recommended plant protection measures were adopted as and when required for raising healthy crop. Harvesting was done manually by hand digger after 164 days after planting in all the five treatments of withholding irrigation, while in other five treatments of harvesting time the garlic bulbs were harvested as per treatments given. The data were collected on quality parameters *viz*., total soluble solids and sulphur content after curing of 20 days on monthly basis.

Observations recorded

Ten bulbs were selected randomly from each treatment in all the replications for measuring their total soluble solids and sulphur content. The observations were recorded at the start of experiment and at monthly interval during whole storage period (240 days) from all four replications.

Total soluble solids (%)

From each replication, 10-20 cloves were cut into small pieces on each date of observation and crushed with pestle and mortar to obtain juice. This juice was used to record the total soluble solids (TSS) values with the help of hand refractometer and expressed in percentage.

Sulphur content (%)

The sulphur was evaluated by extraction method for ICP-AES measurement (Zhao *et al.*, 1994), which was based on the concept of hydrolysis of insoluble organic sulphur compounds into small soluble S molecules.

Statistical analysis

The data were subjected to statistical analysis in OPSTAT (http://14.139.232.166/opstat/index.asp), statistical software developed by CCS, Haryana Agricultural University, Hisar (Haryana), India (Sheoran, 2010).

Results and Discussion

Different treatments of withholding irrigation and harvesting time significantly affected quality parameters *viz.*, total soluble solids and sulphur content (%). Total soluble solids and sulphur content (%) increased continuously up to 150 days of storage, but thereafter, they declined till the end of experiment (240 days) in both cases. The interaction between treatments and storage periods regarding TSS was found non-significant but regarding sulphur content it was significant.

Effect of withholding irrigation on TSS and sulphur content (%) during storage

The trend followed by data in Table 1 and 2 shows that both the parameters increased with the decrease in days to withholding irrigation. The mean TSS and sulphur content was found maximum (40.21 and 0.92%) where irrigation was withheld 7 days before harvesting, which was found statistically at par with treatment where irrigation was withheld 14 days before harvesting, whereas, the minimum (36.52 and 0.83%) was recorded with treatment where irrigation was withheld 35 days before harvesting. The improvement in quality traits like TSS and sulphur content due to irrigation has also been reported by Channagoudar and Janawade (2006), Kumar *et al.,* (2007), Ahmed *et al.,* (2009), Fatideh and Asil (2012), Chopade *et al.,* (1998) and Boas *et al.,* (2011). The maximum TSS and sulphur content in garlic bulbs was recorded when more number of irrigations were applied *i.e*., at 15 days interval (Silabut *et al.,* 2014).

The positive influence of maximum irrigation level on TSS, volatile oil and sulphur content of bulb appears to be due to higher moisture level in the root zone, which might have increased nutrients solubility in soil and consequently higher minerals uptake by the plants and accumulation of carbohydrates, especially in vegetative plant parts, possibly due to increased photosynthetic rate, which led to greater translocation of carbohydrates to reproductive organs (bulb) of the crop (Silabut *et al.,* 2014). Further, higher moisture increased TSS content of onion bulbs, which might be because of better uptake and utilization of nutrients (Patel and Rajput, 2013). On the other hand, it is interesting to know that more number of irrigation decreased the dry matter and sulphur content of onion bulbs (Chung, 1989; Sharda, 2006).

The quality parameters differed significantly among different storage periods also. The mean TSS and sulphur content was noted maximum (39.63 and 0.93%) at 150 days of storage, while the minimum (34.57 and 0.80%) was registered at 0 days of storage. The findings are in close confirmatory with the results of vasanthan *et al.,* (2005) who reported that the increase in TSS content was might be due to loss of water from the bulbs through transpiration and due to the breakdown of complex polymers by hydrolytic enzymes into simpler substances utilized in respiration. They further reported that the increment observed in sulphur content during earlier part of storage period might be because of restructuring of total sulphur within the onion bulbs to form alk(en)yl cystein sulphoxides and the possible reason of decrease in sulphur content in later part of storage was oxidation of sulphur into sulphoxides started taking place after breaking dormancy of onion bulbs.

Effect of different harvesting times on TSS and sulphur content (%) during storage

Both parameters increased with the delay in harvesting (from 150 to 171 days after planting), but in treatment harvesting at 178 days after planting, they decreased again (Table 3 and 4). The mean TSS and sulphur content was found maximum (40.11 and 0.92 %) where harvesting was done 171 days after planting, which was found statistically at par with treatment where the harvesting was done 164 days after planting, whereas, the minimum (35.13 and 0.80 %) was recorded with treatment where harvesting was done 150 days after planting.

Table.1 Effect of withholding irrigation on TSS content (%) of garlic bulb at 30 days interval during storage

Treatment/withholding irrigation (days before harvesting)	Storage period (days)									
	0	**30**	**60**	**90**	**120**	**150**	**180**	**210**	**240**	**Mean**
35	33.64	35.14	36.04	37.37	37.61	38.54	38.06	37.17	35.06	**36.52**
28	34.24	36.45	37.86	38.20	39.58	39.88	38.15	37.28	35.77	**37.49**
21	36.40	37.90	38.83	39.53	40.28	40.78	38.93	38.44	36.52	**38.62**
14	36.73	38.83	39.44	40.63	41.64	42.65	40.74	39.99	39.24	**39.98**
7	37.61	39.83	40.44	40.73	41.80	42.54	40.44	39.67	38.87	**40.21**
Mean	**36.72**	**37.63**	**38.52**	**39.29**	**40.18**	**40.88**	**39.26**	**38.51**	**37.09**	

C.D. at 5% level of significance
Treatments = 0.37
Storage period = 0.49
Treatment × Storage period = NS

Table.2 Effect of withholding irrigation on sulphur content (%) of garlic bulb at 30 days interval during storage

Treatment/withholding irrigation (days before harvesting)	Storage period (days)									
	0	**30**	**60**	**90**	**120**	**150**	**180**	**210**	**240**	**Mean**
35	0.75	0.78	0.81	0.84	0.87	0.88	0.86	0.85	0.83	**0.83**
28	0.76	0.79	0.83	0.86	0.87	0.90	0.88	0.86	0.85	**0.84**
21	0.78	0.82	0.85	0.89	0.92	0.93	0.91	0.89	0.88	**0.87**
14	0.80	0.84	0.87	0.91	0.95	0.97	0.96	0.94	0.92	**0.91**
7	0.80	0.85	0.87	0.92	0.97	0.98	0.96	0.95	0.94	**0.92**
Mean	**0.78**	**0.82**	**0.85**	**0.88**	**0.92**	**0.93**	**0.91**	**0.90**	**0.88**	

C.D. at 5% level of significance
Treatments = 0.37
Storage period = 0.49
Treatment × Storage period = NS

Table.3 Effect of different harvesting times on TSS content (%) of garlic bulb at 30 days interval during storage

Treatment/harvesting time (days after planting)	Storage period (days)									
	0	**30**	**60**	**90**	**120**	**150**	**180**	**210**	**240**	**Mean**
150	31.48	33.39	35.43	36.22	36.76	37.24	35.84	35.18	34.64	**35.13**
157	33.24	35.73	37.64	38.04	38.57	39.16	38.83	38.23	36.91	**37.37**
164	36.65	37.74	39.47	39.85	40.41	41.76	41.26	39.86	38.66	**39.78**
171	37.44	38.53	40.28	40.83	41.54	41.92	41.03	40.74	40.04	**40.11**
178	34.64	35.43	36.58	37.13	37.76	38.83	38.02	37.27	36.04	**36.85**
Mean	**34.57**	**36.16**	**37.84**	**38.40**	**39.01**	**39.63**	**38.85**	**38.20**	**37.18**	

C.D. at 5% level of significance
Treatments = 0.36
Storage period = 0.48
Treatment × Storage period = N.S

Table.4 Effect of different harvesting times on sulphur content (%) of garlic bulb at 30 days interval during storage

Treatment/harvesting time (days after planting)	Storage period (days)									
	0	**30**	**60**	**90**	**120**	**150**	**180**	**210**	**240**	**Mean**
150	0.72	0.75	0.79	0.81	0.83	0.85	0.84	0.82	0.80	**0.80**
157	0.77	0.80	0.83	0.85	0.86	0.89	0.88	0.85	0.83	**0.84**
164	0.82	0.85	0.87	0.90	0.93	0.96	0.95	0.93	0.90	**0.91**
171	0.86	0.87	0.89	0.91	0.93	0.97	0.95	0.94	0.92	**0.92**
178	0.85	0.87	0.88	0.89	0.92	0.96	0.94	0.93	0.91	**0.91**
Mean	**0.80**	**0.83**	**0.85**	**0.87**	**0.90**	**0.93**	**0.91**	**0.89**	**0.87**	

C.D. at 5% level of significance
Treatments = 0.02
Storage period = 0.02
Treatment × Storage period = 0.03

The findings of this investigation corroborate the results of Singh *et al.*, (1995); Smittle and Maw (1988). The value for quality parameters at later stage was recorded maximum due to comparatively low moisture content in the bulbs of these treatments at different periods of storage (Singh *et al.*, 1995). The sprouting in storage was associated with lower levels of total water-soluble solids in the center of bulbs, which was found associated with the early harvest (Wheeler *et al.*, 1998). On the contrary, Kepka and Sypien (1971) and Bottcher (1999) observed that late harvesting is harmful for quality of garlic, as it leads to lower number of dry scales and poor quality of skin.

Both quality parameters differed significantly among different storage period also. The mean TSS and sulphur content was noted maximum (39.63 and 0.93 %) at 150 days of storage, while the minimum (34.57%) was registered at 0 days of storage. The results are in close conformity with those of Singh and Dhankhar (1991) and Robinson *et al.*, (1975) who stated that the decrease in TSS and sulphur content during later period of storage might be due to its utilization in oxidation process. Another reason for the slight reduction could be that as the storage time increases, the bulb dormancy ends, leading to sprouting. Consequently, there will be proportional rise in respiration and carbohydrates metabolism that brings a rapid decline in TSS content of bulbs (Shiferaw *et al.*, 2013). Similar results regarding changes in allyl sulphide content of garlic during storage were also reported by Song *et al.*, (1982).

The present investigation indicates that withholding irrigation and different harvesting times affects the quality parameters of garlic significantly. The study revealed that both quality parameters increased with the decrease in days to withholding irrigation and with delay in harvesting up to 171 days after planting. Therefore, it may be concluded that for better storage irrigation should withheld 14 days before harvesting and crop should harvested at 164 days after planting.

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