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ORIGINAL ARTICLE

Effect of Withholding Irrigation on Shelf Life Of Garlic (*Allium sativum* L.)

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ABSTRACT
Water has been identified as one of the scarce inputs, which can severely restrict agricultural production and productivity unless it is carefully conserved and managed. The effect of withholding irrigation on shelf life of garlic (Allium sativum L.) cv. HG-17 was investigated at Research Farm of the Department of Vegetable Science, CCS Haryana Agricultural University, Hisar during Rabi season in 2013-14. The experiment consisted of five treatments viz., withholding irrigation at 35, 28, 21, 14 and 7 days before harvesting. This trial was laid out in Randomized Block Design for field studies while for laboratory studies Completely Randomized Design was used with four replications. Results revealed that all the losses were observed maximum at the end of storage period i.e., 240 days in treatment where more number of irrigations was applied as compared to the treatment where irrigation was withheld 35 days before harvesting. The minimum physiological loss in weight (27.03%), decay loss on number and weight basis (1.18 and 1.06%), per cent sprouting on number and weight basis (12.34 and 10.38%), average sprout length (1.24 cm) and average sprout weight (46 mg) was registered with treatment withholding irrigation at 35 days before harvesting, while the maximum value for physiological loss in weight (32.99%), decay loss on number and weight basis (2.56 and 2.18%), per cent sprouting on number and weight basis (18.01 and 14.92%), average sprout length (1.51 cm) and average sprout weight (61 mg) at the end of storage was recorded from the treatment where irrigation was withheld 7 days before harvesting. Therefore, from presented experiment it may be concluded that lesser water application is favourable for reducing storage losses in garlic.
***Keywords**: Garlic, bulb, harvesting time, storage losses and characteristics*

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INTRODUCTION

Garlic (*Allium sativum* L.), popularly produced and extensively consumed annual bulb crop that has been cultivated since ancient times and is used as a spice and condiment for many centuries. It is a diploid species which belongs to Alliaceae family with chromosome number, 2n=16 and native of Central Asia and later spread to Mediterranean region [16] [27]. It is the second important and widely cultivated bulb crop after onion [10]. Its cultivation has been encouraged in India on commercial scale due to its multiple uses and export potential. It is consumed in many ways mainly as a spice, seasoning and flavoring for foodstuff involving both green tops and bulbs because of its pungent flavor. The pungency of garlic is due to presence of sulphur containing compound diallyl disulphide. It is grown in many countries, like Egypt, United States of America, China, India, Korea, Thailand, France, Spain, *etc*. The area of garlic during 2015-2016 was 280.95 thousand hectares with production of 1617.34 thousand MT in India [3]. India is the second largest producer of garlic after China and a major exporter of bulb, dehydrated flakes, powder, oil and oleoresins all over the world. 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. In Haryana, garlic-growing districts are Kurukshetra, Ambala and Karnal.

Garlic exhibits greater susceptibility to agro-techniques and environmental conditions and possesses a wide range of variability in bulb and yield traits as well as storability in spite of being vegetatively propagated crop. On irrigated land, the onion crop is regarded as a large consumer of water and under water deficiency its evapo-transpiration decreases and consequently yield too [23] because of that storage behaviour also affected. Irrigation scheduling is one of the most important tools for developing best management practices for irrigated areas [2]. In Haryana, garlic is gaining increasing popularity during recent years on accounts of higher returns 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. 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 [22]. 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. Being solvent, water is pre-requisite to successful garlic production [18] in relation to bulb size, weight and quality [13]. Because of fibrous and shallow root system, it requires adequate moisture for proper establishment, growth, development and storability of bulbs [15]. Efficient use of water is vital for economic production since scarcity and excess of irrigation increases storage losses of garlic [7]. Quality of garlic bulbs can be affected by mineral nutrition, irrigation schedule or rainfall [8]. Excess moisture at harvesting causes fast deterioration like rotting, early sprouting, *etc.* during storage. Both, water and nutrient management for onion production have a significant effect on postharvest behaviour of the produce [5]. These pre-harvest inputs influence the storage behaviour of onion bulbs directly or indirectly [17]. The bulbs grown under low soil moisture regimes are usually smaller and tend to lose more moisture and dry earlier during storage [19]. 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 [20]. In addition, a substantial increase of decomposition in onion during storage with increasing irrigation was reported by [26]. In the contrary, [29] reported that irrigation had only a minor effect on the storage performance and shelf life of onion. Therefore, the aim of study was to determine the effect of withholding irrigation on shelf life of garlic, also to standardize the time of withholding irrigation for maintaining better storage of garlic.

MATERIAL AND METHODS

The experiment was carried out at Research Farm of the Department of Vegetable Science, CCS Haryana Agricultural University, Hisar during 2013-14. The general features of this region are semiarid climate with hot and dry winds during summer and dry severe cold in winter. During whole experimental period the maximum temperature was ranged between 19.5 to 41.0 °C, while the minimum was ranged between 5.6 to 26.9 **°C.** The soil of the experimental field was sandy loam in texture with pH and EC of 8.2 and 0.39 dS/m, respectively. The soil was having available nitrogen, phosphorus and potassium (129, 21 and 291.61 kg/ ha, respectively). The planting was done on October 25, 2013. The experiment was laid out in Randomized Block Design. Five treatments of withholding irrigation were applied *viz*., withholding irrigation 35, 28, 21, 14 and 7 days before harvesting, which replicated four times 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 was 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, K_2O were applied at the time of planting, while remaining nitrogen was top dressed at 30 day after planting. Irrigation 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 treatments. The observations were recorded on storage characteristics like cumulative physiological loss in weight (%), decay loss on both number and weight basis (%), per cent sprouting on number as well weight basis, average sprout length and weight after curing of 20 days. The cumulative PLW, decay loss on number as well as weight basis was recorded at 20 days interval. The sprouting (%) on number as well weight basis, average sprout length and sprout weight was recorded at the end of storage period, *i.e.*, 240 days. The data recorded on different parameters were subjected to statistical analysis in OPSTAT, statistical software developed by CCS Haryana Agriculture University, Hisar (Haryana), India and the mean differences were evaluated by critical difference (C.D.) test at 5% level of significance [32].

RESULTS AND DISCUSSION

Due to loss of moisture from the garlic bulbs through the process of transpiration, the cumulative physiological loss in weight (PLW) increased significantly with the advancement of storage period (Table 1). The data regarding physiological loss in weight of garlic were recorded at 20 days interval during storage period of 240 days and expressed as cumulative physiological loss in weight in percentage. The perusal of data presented in Table 1 reveals that the physiological loss in weight increased consistently with the increase in storage period from starting to end of the experiment up to 240 days. The rate of loss was very rapid in the starting of experiment, but thereafter, it decreased slowly up to the end of storage period. The physiological loss in weight at the end of storage period of garlic exhibited a significant variation among treatments where irrigation was stopped at 35 and 28 days before harvesting. The maximum value for cumulative physiological loss in weight was recorded in treatment where irrigation was withheld 7 days before harvesting, which differed significantly from all other treatments and except where irrigation was stopped 14 days before harvesting, while the minimum was observed where irrigation was withheld 35 days before harvesting at the end of storage period. [9] observed water losses at different humidity and temperatures. Storage loss in onion could be as high as 66% [20]. Pre-harvest inputs influence the storage behaviour of onion bulbs directly or indirectly [17]. Weight loss of onion bulbs is usually known to occur due to transpiration, dehydration, decaying, sprouting, *etc*. and it is generally caused due to prevailing high temperature and high humidity in the environment [25]. Another possible cause for PLW was utilization of reserve food material in respiration process [31]. The increase in loss was observed from beginning to the termination of experiment irrespective of treatments but the rate of increase was highest in starting of storage. The higher weight loss in the starting might be due to higher initial moisture content of the onion bulbs at the onset of the experiment, which in later part went on decreasing [4]. Among different treatments of withholding irrigation (Table 1), the minimum PLW was observed in treatment where irrigation was withheld 35 days before harvesting, while the maximum was recorded in treatment where irrigation was withheld 7 days before harvesting. The results are in close conformity with the results of [1] [4] [12] [24]. As the quantity of water decreased, the storage characteristics improved. The results are in close confirmatory with the results of [8] [14] who reported that higher irrigation increases wastage during storage of onion as it helps in increasing moisture content of bulb. In contrary, [29] stated that irrigation had only a minor effect on the storage performance and shelf life of onion.

Table 1: Effect of withholding irrigation on cumulative physiological loss in weight (%) of garlic bulbs recorded at 20 days interval during storage

Treatment/ Withholding irrigation (days before harvesting)	**Storage period (days)**											
	20	**40**	**60**	**80**	**100**	**120**	**140**	**160**	**180**	**200**	**220**	**240**
35	6.22	8.89	10.88	12.13	14.00	16.37	18.22	20.47	21.87	22.85	24.89	27.03
28	12.82	16.53	18.49	19.93	21.00	22.36	24.30	25.23	26.59	27.76	28.45	30.35
21	14.28	16.21	18.85	20.28	21.09	22.76	24.32	25.45	26.54	28.06	29.62	31.17
14	15.87	18.79	19.95	21.74	23.11	24.01	25.23	26.00	27.90	30.06	31.33	32.89
7	17.56	19.73	21.58	22.43	23.28	25.23	26.92	28.64	29.79	30.66	31.44	32.99
C.D. at 5% level of significance	**1.88**	**0.77**	**0.96**	**1.05**	**1.06**	**0.74**	**0.74**	**0.74**	**0.81**	**0.69**	**0.68**	**0.91**

Microbial spoilage together with water loss and biochemical changes is responsible for the deterioration of freshly harvested produce during storage [11]. The data pertaining to decay loss on both number and weight basis (Table 2 and 3) indicate that from starting to 210 days, no significant decay loss on weight basis was recorded, but thereafter, some decay loss was recorded at 220 days onwards and found increased at the termination of experiment (240 days of storage) in all the treatments of withholding irrigation at different days before harvesting. The results are in line with the findings of [6] who stated that decay loss of onion bulbs increased with the lengthening of storage period due to the attack of several microorganisms, and the most common microorganisms responsible for decaying of onion bulbs during storage were various fungi (*Aspergillus niger*, *A. tumigatus*, *pennicillium rubrum* and *Fusarium* spp.) and bacterium (*Erwinia carotovora*).

Table 2: Effect of withholding irrigation on decay loss (%) during storage (on number basis)

Treatment/ Withholding irrigation (days before harvesting)	Storage period (days)											
	20	40	60	80	100	120	140	160	180	200	220	240
35	0	0	0	0	0	0	0	0	0	0	1.08	1.18
28	0	0	0	0	0	0	0	0	0	0	1.37	1.45
21	0	0	0	0	0	0	0	0	0	0	1.68	1.87
14	0	0	0	0	0	0	0	0	0	0	1.94	2.27
7	0	0	0	0	0	0	0	0	0	0	2.24	2.56
C.D. at 5% level of significance	**N.S.**	**N.S.**	**N.S.**	**N.S.**	**N.S.**	**N.S.**	**N.S.**	**N.S.**	**N.S.**	**N.S.**	**0.24**	**0.20**

It can also be seen from the data in Table 2 and 3 that withholding irrigation at different days before harvesting significantly influenced the decay loss in garlic and the decay loss increased significantly with decreasing days of withholding irrigation before harvesting. The minimum decay loss on both number and weight basis was registered with treatment where irrigation was withheld 35 days before harvesting, while the maximum was observed in treatment where irrigation was withheld 7 days before harvesting. The similar results have also been reported by [4] [24] [28].

Table 3: Effect of harvesting time on decay loss (%) during storage (on number basis)

Treatment/ Withholding irrigation (days before harvesting)	Storage period (days)											
	20	40	60	80	100	120	140	160	180	200	220	240
35	0	0	0	0	0	0	0	0	0	0	0.91	1.06
28	0	0	0	0	0	0	0	0	0	0	1.20	1.29
21	0	0	0	0	0	0	0	0	0	0	1.46	1.67
14	0	0	0	0	0	0	0	0	0	0	1.72	1.98
7	0	0	0	0	0	0	0	0	0	0	1.96	2.18
C.D. at 5% level of significance	**N.S.**	**N.S.**	**N.S.**	**N.S.**	**N.S.**	**N.S.**	**N.S.**	**N.S.**	**N.S.**	**N.S.**	**0.21**	**0.18**

Some of the undesirable changes that may occur during sprouting are weight loss, shrinkage and loss of nutritive value. The sprouting behaviour of garlic bulbs was studied on weight as well as number basis, average sprout length and sprout weight at the end of storage period, *i.e*., 240 days. The sprouting behaviour of garlic bulb was significantly influenced by different treatments of withholding irrigation (Table 4 and 5, respectively). Under ordinary room temperature conditions, the sprouting is a very serious problem in onion bulbs [31]. The treatments of withholding irrigation at different days before harvesting significantly influenced the percent sprouting (on number as well weight basis) also, which was recorded at the end of storage, *i.e*., 240 days. The trend followed by data shows that the sprouting (%) increased with the decrease in days to withholding irrigation at different periods before harvesting. The average sprout length, sprout weight and sprouting percentage on number and weight basis was recorded minimum with treatment withholding irrigation 35 days before harvesting at the end of storage period, while the maximum in treatment where irrigation was withheld 7 days before harvesting. The results are in accordance with the finding of [21] [4] [8]. The major reason of sprouting at the end of storage period might be due to the gradual decrease in growth inhibitor (abscissic acid). [30] found that gibberellins and a growth inhibitor, presumably abscissic acid, play an important role in breaking dormancy of onion bulbs. A substantial increase in decay of onion during storage with increasing irrigation was reported by [26].

Table 4: Effect of withholding irrigation on sprouting (%) at 240 days of storage (on number and weight basis)

Treatments/withholding irrigation (days before harvesting)	Sprouting (%)	
	Number basis	Weight basis
35	12.34	10.38
28	14.13	11.50
21	16.07	13.08
14	17.79	14.17
7	18.01	14.92
C.D. at 5% level of significance	**1.70**	**0.62**

Table 5: Effect of withholding irrigation on average sprout length (cm) and weight (mg) at 240 days of storage

Treatments/withholding irrigation (days before harvesting)	Average sprout length (cm)	Average sprout weight (mg)
35	1.24	46
28	1.30	50
21	1.35	53
14	1.45	58
7	1.51	61
C.D. at 5% level of significance	**0.08**	**3**

CONCLUSION

From presented study, it may be conclude that excess water application leads to various storage losses as maximum losses were observed in all parameters with the treatment where irrigation was withheld at 7 days before harvesting. Therefore, as far as storage life of garlic to be concerned or increased, lesser number of irrigations needs to be apply.

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