Response of Garlic Yield and Storability to Varying Frequencies of Irrigation

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Summary

The experiment was conducted during 2013-2014 and 2014-2015 at the Regional Agricultural Research Station, Ishwardi, Pabna, Bangladesh to find out the appropriate irrigation schedule for optimum bulb yield and subsequent effect of irrigation schedule on storability of garlic. The experiments consisted of four irrigation frequencies (interval of 10, 15, 20 and 25 days) that were laid out in a randomized complete block design with three replications. The results showed that irrigation interval significantly influenced yield and morphological characteristics (plant height, individual bulb weight/plant, number of clove/bulb, clove weight and bulb yield). Irrigation frequency of 10 days interval resulted with the highest bulb yield of 10.48 t/ha with 372 mm of seasonal water used. It was followed by 15 days interval (9.81 t/ha) where 275 mm of seasonal water was used. It was clearly shown that the bulbs lost their weight progressively after all irrigation treatments in storage conditions. Minimum weight loss was obtained at 10 and 15 days interval. From an economic point of view, farmers can take irrigation schedules of 10 or 15 days interval for maximum return where irrigation water is available. At water stress conditions garlic might be irrigated at 20 days interval but consequently bulb yield will be reduced.

Key words

Allium sativum L., irrigation schedule, water use efficiency, storability

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Introduction

Garlic (*Allium sativum* L.) belongs to the family Alliaceae and it is one of the most valuable spices. It is cultivated all over the Bangladesh but especially in North-Western parts during winter season under irrigation mainly for selling between November and April. During this time, majority crops cannot be grown successfully without adequate irrigation. Buwalda (1987) and Choi *et al.* (1980) reported that garlic required adequate moisture from establishment through maturity for better growth and yield and bulb quality. They further reported that the crop could not withstand application of excess water and/or that water deficiency which might cause substantial yield reduction. Garlic has a relatively shallow root system and therefore it is sensitive to moisture stress throughout the growing season. Miko *et al.* (2000) and Bello (2001) reported that garlic is sensitive to moisture stress and high temperature and about 60% reduction in yield has been associated with water stress. The number of irrigation required for garlic depends upon the moisture retention capacity of soil and climatic conditions. Hanson *et al.* (2003a) reported that the highest garlic yield was obtained by irrigating once a week. For constant growth and marketable yield the moisture content of soil should be maintained at optimum level. Delay in moisture supply during the vegetative stage causes stunted growth while no water supply during bulbing may cause splitting or cracking of bulbs and reduced yield. Sula (1990) observed that more frequent irrigation prolonged the growth period by 10-12 days but increased photosynthetic activity thus increased yield and reduced cost per unit of product. Achieved yield varied from 5.28 to 6.16 t/ha by irrigating the crops 3-4 times. The Bangladesh farmers frequently apply irrigation in garlic field injudiciously. The amount of available soil moisture is very important. The problem is finding ways by which available water could be economically utilized. Many researchers found a direct relationship between yield and yield components of bulb crops with available moisture and time of irrigation (El-Bheidi *et al.*, 1983; Baten *et al.*, 1992; Panchal *et al.*, 1992; Pandy and Sing, 1993; Lipinski *et al.*, 1996; Patel *et al.*, 1996; Abo-Sedera and Badr, 1998; Hanson *et al.*, 2003b; Ortega *et al.*, 2004). Thus, the study has been undertaken to find out the appropriate irrigation schedule for optimum bulb yield and garlic storability.

Materials and methods

The experiment was conducted at the Regional Agricultural Research Station, BARI, Ishurdi, Pabna, Bangladesh during 2013-2014 and 2014-2015 to find out the appropriate irrigation schedule for optimum growth and yield of garlic and to find out the subsequent effect of irrigation schedule on storability of garlic. The experimental site was a clay loam having field capacity of 29.2%, permanent wilting point at 14% and bulk density of 1.49 g cm^{-3}. The experiment was laid out in a randomized complete block design with three replications. The garlic variety BARI Roshun-2 was used as a test crop. The unit plot size was 3 × 3 m. Four irrigation schedules: I_1 = Irrigation at 10 days interval, I_2 = Irrigation at 15 days interval, I_3 = Irrigation at 20 days interval and I_4 = Irrigation at 25 days interval were studied in this experiment. Irrigation water was applied up to field capacity by estimating soil moisture content. Soil moisture content was calculated by oven dry method.

For this purpose soil samples were taken from the effective root-zone of the plant which is 0-40 cm. The root zone was divided into three sections: 0-15, 15-30 and 30-40 cm. Soil samples were collected from these three sections with the help of an auger. The amount of water applied to each treatment was calculated on the basis of the soil moisture content at the time of irrigation by using the following expression:

$$d = MC \times BD \times D$$

where:

d = depth of water to be applied
MC = moisture content (%)
BD = bulk density of the soil
D = depth of root-zone to be irrigated

The depth of rooting was considered 30 cm. It is reported that 70% of total moisture is extracted from the 50% effective root zone depth (Michael, 1996). The seasonal crop water use was calculated by the following relationship:

$$SWU = NIR + Rf + \sum_{i=1}^{n} \frac{(Mbi - Mei)}{100} \times A_{Si} X\, D_i$$

where:
SWU = seasonal water use, mm
NIR = total irrigation water depth, mm
Rf = seasonal rainfall, mm
Mbi = moisture percentage at the beginning of the season in the each layer of the soil
Mei = moisture percentage at the end of the season in the each layer of the soil
n = No. of soil layers in the root zone,
D, (This was considered of three layers, 0-15, 15-30, and 30-45 cm)
Di = depth of the each layer of soil within the root zone, mm
Asi= apparent specific gravity of each layer of soil

Water use efficiency was used in evaluating the yield performance and water management practices. The water utilized by the crop was calculated by the following relationship:

$$\text{Water use efficiency (WUE)} = \frac{\text{Yield}\left(\frac{kg}{m^2}\right)}{\text{Seasonal water use (m)}}, \text{ kg m}^{-3}$$

Benefit cost ratio was calculated according to Reddy and Ram (2010) as follows:

$$BCR = \frac{\text{Gross return (Tk.)}}{\text{Total variable cost (Tk.)}}$$

Initial soil moisture of the experimental plot was calculated to be 26.68%, which was maintained by applying light irrigation (20 mm) on the basis of monitoring soil moisture for ensuring emergence (Table 2). Second common irrigation was applied (29 mm) at 30 days after planting (DAP) prior to imposing the treatments to enable the stands to be well established (Table 2). Irrigation treatments were applied after 30 DAP. Garlic bulbs were stored in ambient conditions to see the subsequent effect of irrigation schedule. For calculation of garlic storability bulbs were stored in three replicated baskets for up to 180 days in the storage with airation. Irrigation was stopped 25 days before harvest of garlic. The crop was planted on 10 and 9 November 2013

and 2014, respectively. The bulbs were harvested on 29 March and 3 April 2014 and 2015, respectively. The amount of fertilizers applied was 100-54-167-20-4-1 kg/ha of N-P-K-S-Zn-B, respectively. Half of N and all other fertilizers were applied at final land preparation. Remaining N was applied as top dressing at 25 and 50 days after emergence. Weeding was also done at 25 and 50 days after emergence of garlic. Data on yield and morphological characteristics were taken and analyzed statistically. The mean values were adjusted by LSD at 0.05 levels of probability.

Results and discussion

Effect of irrigation frequencies on yield contributing characters and bulb yield of garlic:

Measured morphological traits (plant height, individual bulb weight/plant, number of clove/bulb and clove weight) were significantly affected by irrigation interval. However, the trend showed a decrease with increase of irrigation interval. In this concern, irrigation at 10 days interval exhibited the highest values of all morphological traits (Table 1). It might be due could be The availability of water at the root zone, which is attributed to 10 days irrigation interval, increased the mobility of nutrients in the soil that consequently increased the minerals uptake by plant and this increased carbohydrate assimilation, photosynthetic and other physiological activity that are necessary for different growth processes that lead to increased bulb yield. Irrigation interval had significant effect on bulb yield in both seasons. As regard the data, increase in irrigation interval significantly decreased bulb yield from 10 to 25 day interval. Ten days irrigation interval showed the significantly higher bulb yield (10.48 t/ha) than the remaining irrigation intervals (Table 1). Irrigation interval of 25 days gave the lowest bulb yield (8.0 t/ha).

Effect of irrigation frequencies on storability of garlic

Garlic storability was noticeably influenced by the irrigation intervals (Fig.1). The total weight loss percentage of stored garlic was significantly different among the irrigation intervals. Irrigation every 10 days followed by 15 days intervals reflected the lowest values of total weight loss percentage of stored garlic compared to 20 and 25 days intervals. There was increasing trend of bulb weight loss at the end of storage (180 days) for 10, 15, 20 and 25 days irrigation intervals, where the values of weight loss were 10.68%, 10.99%, 12.25%, 13.16%, respectively. The rate of bulb weight loss was higher at 10 and 15 days irrigation interval compared to 20 and 25 days intervals up to 60 days storage. Comparatively less weight loss rate was observed at 10 and 15 days irrigation interval compared to 20 and 25 days irrigation interval during storage from 120 to 180 days. It was also revealed that bulbs lost their weight progressively at all irrigation levels during storage conditions. Proper development of bulb is one of the major factors for bulb weight loss during storage. Irrigation applied at 10 and 15 days intervals delivered sufficient moisture at the root zone depth during the growing period, which enhances nutrient uptake capacity of plant that lead to good growth and development of plant as well as bulb, in contrast to to 20 and 25 days irrigation intervals. Bulb weight loss variation occurred during storage in different irrigation interval treatments.

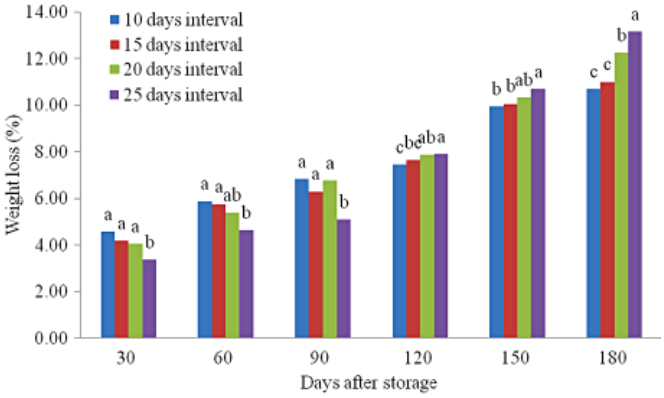

Figure 1. Weight loss of garlic bulb during storage condition

Effect of irrigation frequencies on water use efficiency

Water use efficiency and seasonal water use of garlic is shown in Table 2. Seasonal water use of garlic varied with the variation of irrigation frequencies and it was between 224 and 372 mm. The highest seasonal water use (372 mm) was found at 10 days irrigation interval and the lowest (224 mm) at 25 days irrigation interval. The water use efficiency varied from 2.82 to 3.73 kg m^{-3} depending on irrigation interval and bulb yield. The highest water use efficiency (3.73 kg m^{-3}) was observed at 20 days irrigation interval with bulb yield of 9.32 t ha^{-1} and the lowest water

Table 1. Yield contributing characters and yield of garlic as influenced by irrigation interval (pooled average of 2013-2014 and 2014-2015)

Treatments	Plant height (cm)	Individual bulb weight/plant (g)	Number of clove/bulb (No.)	100-clove weight (g)	Bulb yield (t/ha)
Irrigation at 10 days interval	74.37	31.26	31.61	110.23	10.48
Irrigation at 15 days interval	68.64	28.82	27.24	98.39	9.81
Irrigation at 20 days interval	68.08	24.82	22.51	94.57	9.32
Irrigation at 25 days interval	65.82	16.68	19.52	73.90	8.00
LSD(0.05)	4.97	3.069	3.54	10.98	1.48
CV (%)	3.59	6.05	7.03	5.83	7.86

Table 2. Water use efficiency of garlic under different level of irrigation (pooled average of 2013-2014 and 2014-2015)

Treatment	No. of irrigation	Irrigation for germination ensuring (mm)	Irrigation for plant establishment at 30 DAP (mm)	Irrigation water applied (mm)	Effective rainfall (mm)	Soil water depletion (mm)	Total water use (mm)	Water use efficiency (kg m^{-3})
I_1	9	20	29	300	0	23	372	2.82
I_2	6	20	29	188	0	38	275	3.56
I_3	4	20	29	156	0	45	250	3.73
I_4	3	20	29	127	0	48	224	3.57

I_1 = Irrigation at 10 days interval, I_2 = Irrigation at 15 days interval, I_3 = Irrigation at 20 days interval and I_4 = Irrigation at 25 days interval

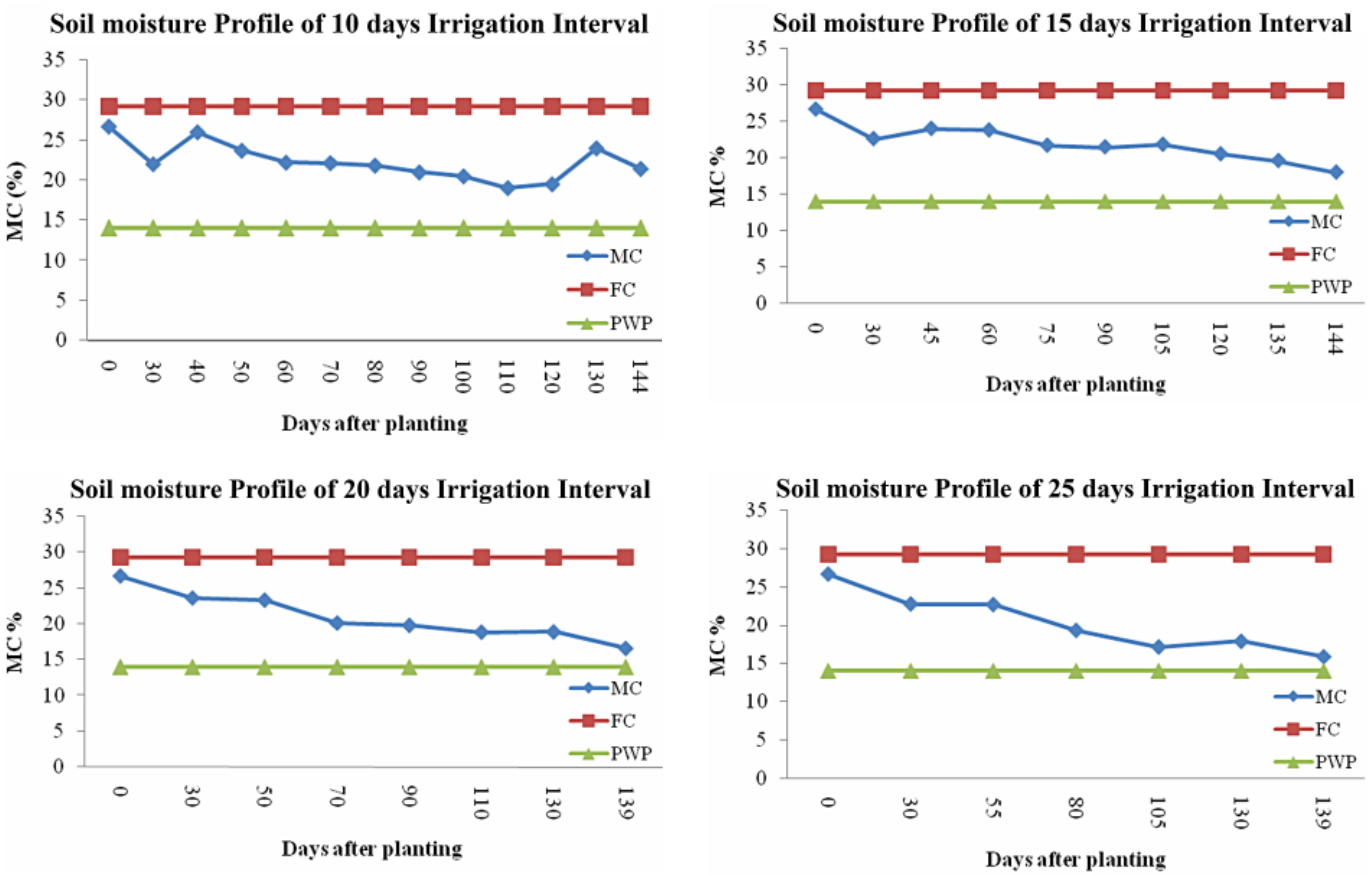

Figure 2. Soil moisture profile of garlic growing period for different irrigation frequencies Legend: MC = Moisture content, FC = Field capacity, PWP = Permanent wilting point

use efficiency (2.82 kg m^{-3}) was with 10 days irrigation interval with bulb yield of 10.48 t ha^{-1}.

Soil moisture profile of garlic growing period at different irrigation frequencies

Soil moisture content gradually decreased with all treatments through garlic growing period (Figure 2). Soil moisture rapidly decreased at treatments I_4 and I_3. The rate of soil moisture decrease was lower at irrigation applied in 10 and 15 days intervals than 20 and 25 days intervals. This result also indicated that garlic was faced with water stress conditions in whole growing period at irrigation treatments of 20 and 25 days intervals. Soil moisture was above 20% through whole growing period with the treatment of irrigation applied at 10 and 15 days intervals that indicated available water was sufficient through whole growing period for growth and yield which increased bulb yield and lengthen duration period near about 3 to 4 days, respectively. On other hand, soil moisture was below 20% from 90 days after planting to harvest and 80 days after planting to harvest at the treatment irrigation applied at 20 and 25 days intervals, respectively, which resulted in reduced bulb yield and accelerated forced maturity. The rate of soil moisture depletion was found the lowest at early growing period and the highest in later growing period.

Table 3. Economic evaluation of garlic under different irrigation schedules (average of two years)

Treatments	Gross return (USD ha^{-1})	Total cost (USD ha^{-1})	Gross margin (USD ha^{-1})	Benefit cost ratio (BCR)
Irrigation at 10 days interval	12998	3335	9663	3.90
Irrigation at 15 days interval	12167	3242	8925	3.75
Irrigation at 20 days interval	11559	3180	8379	3.63
Irrigation at 25 days interval	9922	3149	6773	3.15

Price: Garlic bulb: Tk 100/kg

Economic evaluation

Economic evaluations of garlic under different irrigation frequencies are shown in Table 3. From the study the highest gross return (USD 12998 ha^{-1}), gross margin (USD 9663 ha^{-1}) and benefit cost ratio (3.90) were obtained with 10 days irrigation interval followed by 15 days irrigation interval. The lowest gross return (USD 9922 ha^{-1}), gross margin (USD 6773 ha^{-1}) and benefit cost ratio (3.15) were recorded for 25 days irrigation interval. A positive effect for different irrigation intervals on economic return was clearly observed and it agrees with the finding of Ali *et a.,* (2008) who reported that yield or net economical return per unit water consumed or irrigation depth (WP) or marginal productivity are good indicators for assessing or evaluating the performance of irrigation strategies.

Conclusion

Irrigation applied at 10 days interval for garlic cultivation used 372 mm seasonal water and obtained maximum bulb yield with long term conservation in storage conditions, sacrificing minimum weight loss. From an economic point of view, it was observed that irrigation frequency of 10 days interval was economically feasible for getting maximum return.

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