Irrigation Management for Garlic Cultivars for Higher Yield and Water Productivity under Zero Tillage Condition

Abstract

The significant increase in the scarcity of water for farming purposes and high price of energy required have made it essential to improve water productivity in crops.An experiment was conducted at the farmer's field of Haybatpur and ChalanBeel (Gurudaspur) of Natorefor consecutive two years to develop appropriate irrigation management practice for higher yield of garlic. The experiment consisted of four treatments: farmer's irrigation practice (T_1); Four irrigation frequency (1^{st}:Irrigation @ 20-25 days after sowing(DAS) + 2^{nd} to 4^{th} Irrigation @23-26 days interval) (T_2); Three irrigation frequency (1^{st}: at 20-25 DAS + 2^{nd}: at 45-46 DAS + 3^{rd}: at 60 DAS) plus organic matter at basal dose @ 2kg decimal^{-1} (T_3); Three irrigation frequency (1^{st}: at 20-25 DAS + 2^{nd}: at 45-46 DAS + 3^{rd}: at 60 DAS) (T_4). The cultivars used were Binarosun-1 (V_1) and Italy hybrid (V_2). The highest yield (12.1 t ha^{-1}and 12.5 t ha^{-1}at 2021 and 2022 respectively) as well as BCR was obtained intreatment T_3.Treatments were set to increase the efficiency of water use by 25-40% than conventional practices.Based on the results,garlic productionin Natoreis suggested with the application of three times irrigation and organic matter at basal dose with zero tillage practice.

Keywords: Irrigation, zero tillage, yield, BCR, garlic.

1.Introduction

Garlic (Allium sativum L.)is a member of the Alliaceae family. This species is an indispensable annual herbaceous spice.It is the second most extensively cultivated Alliumcrop, next to onion in the world [1,2]. Garlic is grown largely as a spice crop in Bangladesh;however, production is substantially lower than in other garlic farming nations in the world. The average yield of garlic worldwide is around 10 tons per hectare, with China being the leading producer, accounting for more than half of global production [3].

Zero tillage is the best option because crop residues kept in the soil decrease evaporation, manage soil temperature, reduce soil erosion, minimize overall cultivation costs, improve soil organic carbon availability, improve water use efficiency, and higher crop yield for sustainable crop production [4].Typically, conventional tillage is used to prepare the ground for garlic cultivation. Garlic is being produced in the "Chalanbeel" area of Gurudaspur,Natore, Rajsahi division of Bangladesh, using a zero-tillage mulched system. Under this approach, farmers grow garlic on the damp soil after floodwaters recede. Farmers harvest T-aman rice using only a little portion of the straw; the majority of the straw is

used to cover garlic. Typically, they tillage nothing at all. They just dip the cloves in the muddy soil, and then cover with a thick layer of the rice straw mulch. In Natore and Pabna districts of Bangladesh, about 16905 hectares of land are farmed using mulches and no tillage, accounting for 40% of the country's total garlic production[5].

Garlic is extensively cultivated in many countries of the world including Bangladesh as a popular spice crop. Garlic is also a rich source of carbohydrate and phosphorus [6]. Garlic yield is low due to the lack of inadequate soil, water, and other management practices. Successful garlic cultivation largely depends on the optimum cultural management practices.

The ideal growing conditions for garlic are well-drained, organic matter-rich soils. The best soil types for garlic are sandy loam or loam. Reduced yields and marketable bulbs will result from drought or excessive moisture. It's also been demonstrated that well-composted manure, especially on low organic matter soils, works best when applied and integrated at a rate of 20 to 30 tons per acre [7].For commercial production, clay, silt, and sandy loams are recommended. The soil should have a pH between 6.8 and 7.2, be well-drained, rich in organic matter, and be able to retain moisture during the growing season. The growth of plants is inhibited by lower pH values, and soil pH below 5.0 can potentially cause plant death[8].Garlic grows well on fertile soil. N, P and K are referred to as the primary macronutrients. The nitrogen (N) requirements of garlic are moderate to high. Nitrogen recommendations are depending on the amount of organic matter and historical crop production. The growth-promoting impact of potassium on garlic was evident. N and K significantly boosted plant height, leaf count, stem circumference, etc. Increased nitrogen application rates had a major impact on fresh bulb output. Fresh bulb production was shown to significantly increase in 1998 when nitrogen levels were increased from 0 to 120 kg ha^{-1}. The yield was further decreased by increasing to 240 kg Nha^{-1} [9]. Garlic is susceptible to dry soil conditions and has a rather thin root system. The kind of soil will determine how much water should be applied. In order to prevent the available water holding capacity from falling below around 50%, enough irrigation should be provided. According to [10], First irrigation is given so on after sowing and later field is irrigated after 10 to 15 days until bulb begin to develop. There should not be scarcity of moisture in the growing season to have best bulb development. The last irrigation should be given 3 days before harvesting for making it easy without damaging the bulbs. It can be irrigated either flooding in basin or border strips.Allium sativum L. is a crop that takes four and a half to five months to mature. It is suitable for harvesting when the leaves begin to turn yellow or brown and begin to dry up, which normally happens a month or so after the seed stalks appear. In order to make the bulbs hard and extend their shelf life, the plants are then removed or uprooted using a country plow and placed in little bundles. These bundles are then left in the field or in the shade for two to three days to cure and dry [11].

In the dry parts of Rajshahi, Nilphamari, Syedpur, Meherpur, and Pabna, producing garlic often involves creating an ideal soil tilth and keeping soil moisture levels close to field capacity. For the cultivation of garlic, farmers in the Nilphamari district often employed the tillage method, 10 × 15 cm plant spacing, cowdung, urea, TSP, MP, and in certain cases, DAP, 20–30 days interval irrigation, and flat planting strategy. The majority of farmers in the Sirajgonj district employed a flat system, 20–30days interval irrigation, urea, cowdung, 10 cm x 10 cm plant spacing, DAP, TSP, and MP instead of tillage[12].When compared to traditional garlic production methods, the zero-tillage technology lowered production costs by 33%, resulting in maximum financial advantage[13].These include judicious manuring, efficient use of residual soil moisture and mulching [14].

Garlic cultivation has several problems that contribute to low or reduced yields.Garlic is susceptible to high temperatures and moisture stress, and water stress has been linked to a 60% output drop[14]. The present study was conducted to develop appropriate irrigation management practice for higher yield of garlic.

2.Materials and Method

The experiment was conducted at the farmer's field of Haybatpur and ChalanBeel (Gurudaspur) of Natoreduring 2021 and 2022 covering Lower Ganges River's Agro-ecological Zone-12 (AEZ)to develop appropriate irrigation management practice for higher yield of garlic. The experiment consisted of four treatments: farmer's irrigation practice (T_1); Four irrigation frequency (1^{st}:Irrigation @ 20-25 DAS + 2^{nd} to 4^{th} Irrigation @23-26 days interval) (T_2); Three irrigation frequency (1^{st}: at 20-25 DAS + 2^{nd}: at 45-46 DAS + 3^{rd}: at 60 DAS) plus organic matter at basal dose @ 2kg decimal^{-1} (T_3); Three irrigation frequency (1^{st}: at 20-25 DAS + 2^{nd}: at 45-46 DAS + 3^{rd}: at 60 DAS) (T_4). The cultivars used were Binarosun-1 (V_1) and Italy hybrid (V_2).The cloves of garlic were plantedon 10 November 2021 and the next year on 12 November 2022. Randomized complete block design (RCBD) with split plot arrangement was used for the experiment by assigning the irrigation in the main plots and cultivars in the sub-plots.

In case of conventional tillage and puddling conditions, cow dung was applied in the plot and mixed well with the soil by spading. But under zero tillage conditions, it was applied on the soil.

2.1 Data Recording

The crop was always kept under careful observation.Irrigation was applied according to the objectives. Ten plants were selected at random from each plot and plant heights (cm), bulb diameter (cm), bulb weight (gm), number of cloves per bulb were recorded. The crop was harvested on the 25March, 2022 for the 1^{st} year and on the 27 March, 2023 for the 2^{nd} year experiment. Yield of bulb per plot was measured and it was converted into yield per hectare in metric ton.The statistical analysis was performed using statistical software "Statistix10" (version 10.0).

2.2 Weather pattern of the study area

Although garlic can grow in almost any environment, it prefers low temperatures and thrives in regions with mean monthly growing temperatures between 12°C and 24°C. Relatively high temperature up to 30°C is required for optimum bulb development but cooler condition in the early stages flavor vegetative growth. Both vegetative and bulb development are negatively impacted by excessive humidity and rainfall.The crop is therefore normally grown in low rainfall areas with irrigation during the early vegetable growth. Short days are ideal for bulb development, but extremely hot and extended days are not favorable to bulb growth [11].

Fig 1& 2: Rainfall pattern during growing period of garlic at 2021, 2022 & 2023

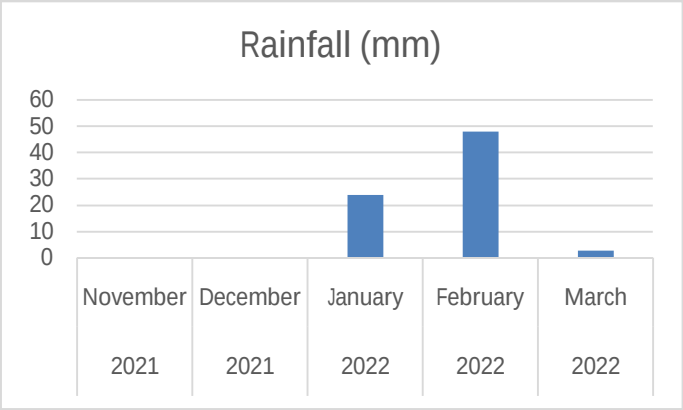
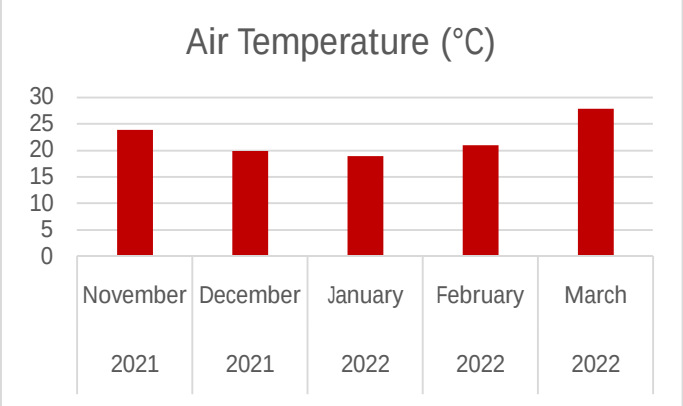
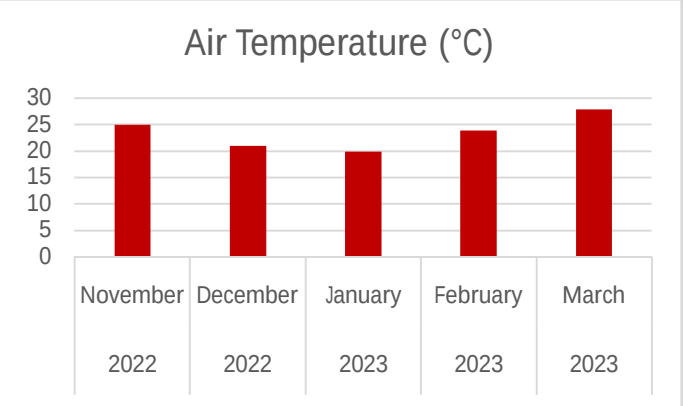


Fig 3 & 4: Air temperature during growing period of garlic at 2021, 2022 & 2023





Source: https://www.timeanddate.com/weather/bangladesh

3.Result and Discussion

3.1 Results of 2021

The treatments demonstrated insignificant effect in every parameter except bulb diameter (**Table 1**). The highest yield (12.1 t ha^{-1}) was obtained in three irrigation frequency (1^{st}: at 20-25 days after sowing + 2^{nd}: at 45-46 DAS + 3^{rd}: at 60 DAS) plus organic matter at basal dose @ 2kg $decimal^{-1}$(T_3).The cultivars demonstrated significant effect in every parameter except number of cloves/ bulb and bulb diameter.

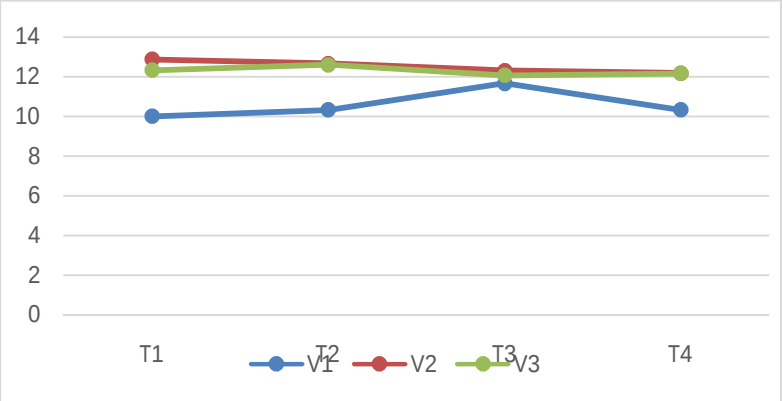
Local cultivar namely 'China hybrid' showed the highest yield (12.5 t ha^{-1}). Garlic grew and produced more when different mulches (rice straw, water hyacinth, and Curcuma amada leaf) were used. The rice straw mulch had the same results as the water hyacinth mulch in terms of growth metrics and bulb production[16]. Garlic production and features that contribute to yield were significantly impacted by varying tillage practices.Adoption of zero tillage practices can increase the efficiency of water use by 25-40% [17].In this experiment, we saved almost 35% water use than the conventional practice.Puddling and zero tillage produced higher yield compared to normal or conventional tillage method. Soil organic matter was higher in zero tillage and puddling than the conventional production method. Moreover, garlic is a shallow rooted plant and it needs continuous moisture supply to the soil. More extensive root development and deeper water storage in the soil profile were encouraged by zero tillage [18].The treatment combination of zero tillage with rice straw mulch produced the highest yield (12.00 t ha^{-1}) while the lowest yield (6.12 t ha^{-1}) was obtained from the combination of zero tillage with no mulch [14].

Table 1. Mean effects of treatments and cultivars on yield and yield attributing characters

Treatment	Plant height (cm)	Bulb Diameter (cm)	Bulb Weight (gm)	No. of Clove/Bulb	Yield (t ha^{-1})
T_1	65.6	3.5 ab	18.5	20.8	11.73
T_2	63.3	3.5 a	18.6	21.3	11.86
T_3	65.5	3.5 ab	19.0	22.8	12.01
T_4	66.9	3.3 b	18.1	20.8	11.56
F-test (at 5%)	NS	S	NS	**NS**	NS
Cultivars					
V_1 (Binarosun-1)	63.2 b	3.3	16.7 b	22.4	10.58 b
V_2 (China hybrid)	68.3 a	3.5	19.6 a	20.2	12.50 a
V_3(Italy hybrid)	64.4 b	3.5	19.3 a	21.7	12.29 a
F-test (at 5%)	S	NS	S	**NS**	S

Note: *Means with the same letter are not significantly (statistically) different at 5% probability level by Tukeys's Honest Significant Difference (THSD) test.*

Fig5. Interaction effects of treatments and cultivars on grain yield.



In case of interaction effects (**Fig 5**), treatment T_1 (farmer's practice)and variety V_2(China hybrid) produced the highest yield. The cultivars V_2 and V_3 produced higher yield compared to V_1 under all treatments.

3.2 Results of 2022

The same experiment was conducted at the farmer's field of Haybatpur and Chalan Bill (Gurudaspur) of Natore during Rabi season 2022 and collected bulb yield data for comparing the previous year's data. Table 2 shows the yield variation of garlic at Haybatpur and Chalan Bill (Gurudaspur),Natore during 2022.

Table 2. Mean effects of treatments and cultivars on yield at Haybatpur, Natoreand Chalan Bill (Gurudaspur), Natore

Treatment	Bulb Yield ($t\ ha^{-1}$)	
	Haybatpur	Chalan Bill
T_1	9.57b	7.45
T_2	11.39ab	8.33
T_3	12.54a	8.83
T_4	11.13ab	7.88
F-test (at 5%)	**S**	NS
CV	11.72	10.94
Cultivars		
V_1(Binarosun-1)	10.65	8.00
V_2(Italy hybrid)	11.66	8.24
F-test (at 5%)	**NS**	NS
CV	14.15	12.36

Note: Means with the same letter(s) are not significantly (statistically) different at 5% probability level by Tukeys's Honest Significant Difference (THSD) test.

The treatments demonstrated significant effect on yield for the location of Haybatpur(Table.2). The highest yield (12.54 t ha^{-1}) was obtained with the application of three times irrigation(1^{st}: at 20-25 days after sowing + 2^{nd}: at 45-46 DAS + 3^{rd}: at 60 DAS) + Organic matter at basal dose @ 2kg $decimal^{-1}$ (T_3). Local cultivar namely 'Italy hybrid' showed the highest yield.In case of interaction effects, treatment $T_3$and variety V_2 produced the highest yield. The cultivars V_2 produced higher yield compared to V_1 under all treatments.

3.3Economic Analysis

The net return and BCR (**Table 3**) of crop yield is presented on the basis of treatments applied in the experiment.

Table 3. Treatment wise Net return and BCR of grain yield during 2021

Treatment	No. of irrigation After treatment started (nos.)	Net Return	BCR
T_1	5	528182	3.25
T_2	4	539232	3.32
T_3	3	551582	3.41
T_4	3	517194	3.21

Table 4. Comparison of BCR of Garlic production at two locations

Treatment	**BCR**	
	Haybatpur	Chalan Bill
T_1	2.62	2.04
T_2	3.19	2.33
T_3	**3.56**	**2.50**
T_4	3.08	2.18

The BCR of garlic production was found positive for all cases (Table 3).The highest net return (551582Tk. /ha) and the highest BCR of 3.41 was obtained fromthe application of three times irrigation(1^{st}: at 20-25 days after sowing + 2^{nd}: at 45-46 DAS + 3^{rd}: at 60 DAS) + Organic matter at basal dose @ 2kg decimal^{-1} (T_3).

The highest net return (196647Tk. /ha) and the highest BCR of 2.90 was found from zero tillage with rice straw. Garlic production under zero tillage with water hyacinth mulch gave the next highest net return of Tk.193703 and gave second highest BCR of 2.87. Therefore, growing garlic with no tillage and covering it with rice straw or water hyacinth mulch was a highly beneficial production method[14].

In this study, the highest BCR was found in treatment T_3 in both the locations.Garlic production was found profitable in the Natore area and the highest yield and BCR was found with the application of three times irrigation and organic matter at basal dose with zero tillage practice.

4. Summary and Conclusions

In general, well-drained soil with a high organic matter concentration is ideal for garlic growth. For commercial production, clay loam, silt, and sandy soils are advised. To increase yields and water productivity, irrigation management is essential for garlic varieties, especially when zero tillage is used.By understanding water requirements, irrigation methods, zero tillage practices, mulching, cultivar selection, fertilization and soil health, monitoring and adjustment of weather parameters, implementing training and education etc., garlic growers can improve both yield and water productivity under zero tillage conditions, contributing to sustainable agricultural practices.

Disclaimer (Artificial intelligence)

NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

5. References

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