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Water use efficiency and yield of garlic responses to the irrigation system, intra-row spacing and nitrogen fertilization

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Abstract

This study was conducted to investigate the yield and water use efficiency of garlic responses to the irrigation system, intra-row spacing and nitrogen fertilization. The field experiments comprised two irrigation systems of furrow and drip (tape) systems, intra-row spacing of 8 and 12 cm and nitrogen fertilization treatments of 0, 60 and 120 kg ha^{-1}. Results revealed that produced yield by two irrigation systems were approximately similar (13,045 kg ha^{-1}) in two cropping years. In addition, with varying intra-row spacing from 12 to 8 cm, the yield was increased by 23%. Application of 60 and 120 kg ha^{-1} fertilizer for plant with space of 8 cm produced the highest yield and application of 0 and 120 kg ha^{-1} fertilizer for space of 12 cm produced the lowest yield. Application of drip system produced the highest WUE with the average of 5.2 kg m^{-3} and obtained WUE by furrow system averaged 2.7 kg m^{-3}. Saved water by drip relative to furrow system was about 50%. Consequently, to achieve the optimum yield and WUE it is recommended that garlic should be planted with intra-row spacing of 8 cm with fertilizer of 60 kg ha^{-1} by drip (tape) irrigation system under agro-climatic condition of Ekbatan, Iran.

Key words: Garlic yield, water use efficiency, drip irrigation.

Introduction

Garlic (*Allium sativum* L.) is one of the oldest bulb crops used for culinary and medical purposes. Garlic production in the world is 15.7 million tons with an average of 13 t ha^{-1} in 2007 [2]. Optimum yield of this bulb crop depends on well-managed irrigation, fertilization and cultivation practices. Nevertheless, much research has not been completed on garlic irrigation and fertilization. However, the following findings are available. Jamroz *et al.* [4] suggested the optimum planting spacing of garlic to be 8 cm in agro-climatic condition of Peshawar. Kilgori *et al.* [5] recommended spacing of 10 cm (with produced cured bulb yield of 8430 kg ha^{-1}) for planting local garlic in Sokoto, Nigeria. Adekpe *et al.* [1] found that the higher bulb yield was obtained with planting at 5 cm intra-row spacing. Kilgori *et al.* [6] reported that applying 120 kg N ha^{-1} produced the highest yield in Nigeria. Hanson *et al.* [3] concluded that garlic yield is a linear function of applied water. Applying of sprinkler line source did not change garlic yield and the highest yield obtained from weekly irrigation. Patel *et al.* [8] investigated garlic yield under drip and surface irrigation methods and different nitrogen levels and reported a linear function between yield and applied water, as well. Garlic is grown on some 4100 ha with an average production of 7.3 t ha^{-1} in Iran [2]. However, to achieve optimum yield and water use efficiency of garlic suitable irrigation system, planting space and optimum nitrogen rate are unknown. Accordingly, this study was conducted to investigate the yield and water use efficiency of garlic responses to the drip and furrow irrigation systems, intra-row spacing and nitrogen fertilization.

Materials and Methods

The field experiments were conducted at the Agricultural Research Station of Ekbatan, Iran, with latitude of 34º52´N, longitude of 48º32´E and a mean sea level elevation of 1730 m. Field soil was loam with average bulk density (Bd) of 1.43 g cm^{-3}, moisture at field capacity (FC) and wilting point (WP) in depth of 0-50 cm 21 and 9.6%, respectively, in the first year and clay loam with Bd of 1.35 g cm^{-3}, moisture at FC and WP 26 and 13%, respectively, in the second year. Some meteorological factors such as rainfall, air temperature and relative humidity during growing seasons are shown in Table 1. Experimental sites received 240 and 210 mm water from rainfall in two consecutive years.

Local cultivar of garlic (*Allium sativum* L.) was planted on the first week of November in both cropping years. Each plot consisted of six rows, 30 m long, on three ditches with spacing of 50 cm (2.3×30 m^2 plots). The experiments were conducted with a randomized complete block design as split-split plots with three replications for two years of 2004-2005 and 2005-2006. This design consisted of two irrigation systems of furrow and drip (tape) systems, intra-row spacing of 8 and 12 cm, and nitrogen fertilization treatments of 0, 60 and 120 kg ha^{-1}. Nitrogen was applied as one-third on planting, one-third in the first half of May and one-third in the first half of June. The applied water volume was measured by a flow meter. Runoff was measured by Washington State College (WSC) flume in furrow system.

After maturity on 27 June, yield (Y) and water use efficiency (WUE) were measured in all plots. Analysis of variance techniques

were applied to statistically analysis of experimental data. To compare treatment means Duncan's multiple range tests was used. Saved water (SW) by drip (tape) relative to furrow system was estimated as follows [7]:

$$SW\ (\%) = 100\ (1-(AW_{Drip}/AW_{Furrow})) \quad (1)$$

where AW_{Drip} and AW_{Furrow} are applied water by drip and furrow systems in m^3. In this study water use efficiency (WUE in kg m^{-3}) was estimated as yield in kg per applied water in m^3.

Results and Discussion

Yield: Produced garlic yield, respectively, averaged as 13,091 and 12,999 kg ha^{-1} by applying furrow and drip systems. Produced yield by two systems was approximately similar (Table 2) in two years.

The yield was significantly ($p \leq 0.05$) influenced by intra-row spacing. With varying spacing from 12 to 8 cm, the yield was increased 23% (Table 2). Average yield from spacing of 12 and 8 cm was 11,709 and 14,380 kg ha^{-1}, respectively. This optimum intra-row spacing is in agreement with recommended space [4] to produce the highest yield. The result is conflict with findings of Kilgori *et al.* [5] and Adekpe *et al.* [1].

The yield response to fertilization treatments was similar (Table 2). Kilgori *et al.* [6] reported that applying of nitrogen 120 kg ha^{-1} produced the highest yield. In this study, the interaction between intra-row spacing and fertilization treatments on yield was significant ($p \leq 0.05$). So that applying of 60 and 120 kg ha^{-1} fertilizer for plant with space of 8 cm produced the highest yield and applying of 0 and 120 kg ha^{-1} fertilizer for space of 12 cm produced the lowest yield (Table 3). Consequently, to obtain the optimum yield garlic should be planted with intra-row spacing of 8 cm and 60 kg ha^{-1} fertilizer and drip (tape) irrigation system should be applied.

Water use efficiency: Water use efficiency of garlic, affected by different experimental treatments in two cropping years, is shown in Table 4. In general, applying of drip irrigation system produced the highest WUE with the average of 5.2 kg m^{-3} and obtained WUE by furrow system averaged 2.7 kg m^{-3}. Difference in WUEs is due to different water amount applied and similar yields. Applied water in drip system was 2535 and 2442 m^3 ha^{-1} and in furrow system 4505 and 5375 m^3 ha^{-1} in two consecutive years. Accordingly, acquired WUE by drip system was approximately two times of that by furrow system and saved water by drip relative to furrow system was 44 and 55% in two years, respectively. As shown in Table 4 WUE increased with decreasing intra-row spacing. Different rates of fertilizer produced similar water use efficiency.

Interaction between irrigation systems, intra-row spacing and nitrogen fertilization treatments on water use efficiency was significant in the second year ($p \leq 0.05$). All plots under furrow irrigation had the lowest WUE. Under drip irrigation, plots with intra-row spacing of 8 cm and fertilization of 120 kg ha^{-1} and with intra-row spacing of 12 cm and fertilization of 60 kg ha^{-1} had the highest WUE (7.2 kg m^{-3}). Interaction between irrigation systems and intra-row spacing on water use efficiency was significant over two years ($p \leq 0.05$). In general, plots with intra-row spacing of 8 cm with drip irrigation had the highest WUE (Table 5). Applying of furrow irrigation for intra-row spacing of 12 cm produced the lowest WUE, as well. Consequently, to have the optimum WUE, garlic should be planted with intra-row spacing of 8 cm and irrigated with drip (tape) system under agro-climatic condition of Ekbatan, Iran.

Conclusions

Responses of yield and water use efficiency of garlic to the drip and furrow irrigation systems, intra-row spacing and nitrogen fertilization were investigated in this study. The findings support the following conclusions. Optimum yield was acquired by fertilization of N 60 kg ha^{-1} and use of drip (tape) irrigation system and intra-row spacing of 8 cm. Optimum water use efficiency of garlic was obtained by drip (tape) system with intra-row spacing of 8 cm. These findings can be applied in environment similar to Ekbatan, Iran, and further studies are needed to other agro-climatic conditions. Also, economic analysis is needed for the adaptation of drip irrigation on garlic.

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Table 1. Rainfall, air temperature and relative humidity during growing seasons.

	Rainfall (mm)		Temperature (ºC)		Relative humidity (%)	
	2004-2005	2005-2006	2004-2005	2005-2006	2004-2005	2005-2006
Nov.	29.77	16.99	6.67	5.63	60.77	63.87
Dec.	39.40	18.66	-0.60	2.20	67.80	69.19
Jan.	51.43	51.23	-5.50	-1.30	75.63	78.49
Feb.	37.37	47.36	-3.27	3.33	67.27	59.03
Mar.	34.03	21.10	6.20	7.80	54.30	48.31
Apr.	31.87	43.13	10.83	11.80	44.20	54.07
May.	14.57	9.96	15.93	16.70	44.00	43.83
Jun.	1.67	1.80	20.63	21.50	35.97	35.97
Jul.	0.00	0.00	24.00	24.30	31.00	33.69

Table 2. Garlic yield affected by irrigation system, intra-row spacing and fertilization treatment in two years.

	2004-2005	2005-2006
Irrigation systems		
Drip	12.461±451 b	13.721±837 a
Furrow	13.264±542 bc	12.733±695 ab
Intra-row spacing		
12 (cm)	12.069±459 bc	11.350±526 c
8 (cm)	13.656±543 ab	15.104±723 a
Fertilization		
N 0 (kg ha^{-1})	13.158±453 a	12.040±650 a
N 60 (kg ha^{-1})	13.183±882 a	14.217±970 a
N 120 (kg ha^{-1})	12.246±557 a	13.425±1108 a

Table 3. Garlic yield affected by interaction of intra-row spacing and fertilization treatment in two years.

	Fertilization N (kg ha^{-1})		
	0	60	120
2004-2005			
Intra-row spacing			
12 cm	12.067±386 bc	12.733±1206 abc	11.408±6091 c
8 cm	14.250±528 a	13.633±1373 bc	13.083±843 abc
2005-2006			
Intra-row spacing			
12 cm	11.363±970 c	11.454±790 c	11.233±1116 c
8 cm	11.717±857 ab	16.979±683 a	15.617±1493 bc

Table 4. Water use efficiency of garlic affected by irrigation system, intra-row spacing and fertilization treatment in two years.

	2004-2005	2005-2006
Irrigation systems		
Drip	4.9±0.2 b	5.6±0.3 a
Furrow	2.9±0.1 c	2.4±0.1 c
Intra-row spacing		
12 (cm)	3.7±0.3 ab	3.4±0.3 b
8 (cm)	4.1±0.3 ab	4.6±0.5 a
Fertilization		
N 0 (kg ha^{-1})	4.1±0.4 a	3.6±0.4 a
N 60 (kg ha^{-1})	4.0±0.3 a	4.3±0.6 a
N 120 (kg ha^{-1})	3.8±0.3 a	4.1±0.7 a

Table 5. Interactive effects of irrigation system and intra-row spacing on WUE.

	2004-2005		2005-2006	
	Irrigation system			
	Drip	Furrow	Drip	Furrow
Intra-row spacing				
12 (cm)	4.8±0.3b	2.7±0.1cd	4.6±0.3b	2.1±0.2d
8 (cm)	5.1±0.2b	3.2±0.2c	6.6±0.4a	2.6±0.9cd