Environment Conservation Journal 17 (3) 117-123, 2016
ISSN 0972-3099 (Print) 2278-5124 (Online)
Abstracted and Indexed

Influence of farm yard manure and inorganic N fertilization on performance of garlic under different irrigation regimes

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Received: 28.07.2016 **Revised: 11.10.2016** **Accepted: 12.11.2016**

Abstract

Results of two years field study revealed that farm yard manure improved bulb circumference, bulb weight, number of cloves, bulb yield, N uptake, crude protein content and irrigation water use efficiency. Irrigation based on irrigation water/pan evaporation (IW/PAN-E) =1.6 and 1.2 produced significantly higher garlic bulb yield and bulb weight than that obtained with IW/PAN-E=0.8, but IW/PAN-E =1.2 used less irrigation water than that with IW/PAN-E =1.6. Garlic yield significantly increased with N application upto 125 kg ha^{-1}. Fertilizer N increased bulb size, weight and irrigation water use efficiency. Crude protein content increased with farm yard manure upto 150 kg ha^{-1} of N and IW/PAN-E =1.6, while upto 125 kg ha^{-1} of N and IW/PAN-E =1.2 without farm yard manure. Water use efficiency decreased with irrigation frequency.

Key Words: Allium sativum, manure, nitrogen, yield, water use efficiency

Introduction

Garlic has a relatively sparse, shallow root system and is sensitive to moisture stress. Water and nutrients are the two most important factors for proper growth and yield. In garlic, bulb initiation and development are the most critical stages for adequate water. Imbalanced fertilizer use is one reason for low crop yields. Increases in cost of chemical fertilizers, particularly N, and concerns about pollution has focused attention on combined use of organic and inorganic nutrients (Bhandari*et al.*, 2012 and Zakari*et al.*, 2014). Organic manures improve soil physical, chemical and biological conditions; are economically viable and ecologically sound but are limited in availability (Yahaya, 2008). Integrated use of chemical fertilizers and organic manures can be an option to supply adequate nutrition (Kharche*et al.,* 2013).

Optimum irrigation and fertilizer requirements of garlic vary with soil, agro-climatic conditions and varieties. Information regarding fertilizer and irrigation response of garlic is lacking. The present study aimed to investigate the growth, yield, N-uptake and some quality characters of high yielding cultivar of garlic (Punjab Garlic-1) in response to integrated nutrient management under various irrigation regimes.

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Material and Method

A field experiment was conducted for two years (2006 to 2008) on a sandy loam soil at the Research Farm, Department of Soil Science, Punjab Agricultural University, Ludhiana (30^{o} 56'N, 75^{o} 52'E), India. The soil contained 61.2% sand, 20.4% silt and 18.4% of clay, had a bulk density 1.47 Mg m^{-3}, pH 8.5, EC 0.202 dS m^{-1} and organic carbon content of 0.41%. Available N, P and K contents were 112.2, 19.1 and 140 kg ha^{-1}, respectively that fall in medium fertility level for these nutrients. Available soil moisture in the 180 cm profile, as determined by the difference in soil moisture storage between 0.33 to 15 bars, was 21 cm. The experiment was arranged in a split-split plot with the main treatment being rate of farm yard manure (FYM) at 0 and 50 Mg ha^{-1} (fresh weight basis). The first split was level of irrigation determined on the basis of irrigation water/pan evaporation (IW/PAN-E) and the second split was N level. A complete dose of P_2O_5 (60 kg ha^{-1}) and K_2O (60 kg ha^{-1}) fertilizers recommended for cultivation in Punjab state (Dhillon, 2015) were applied before sowing.The N fertilizer (0, 100, 125 and 150 kg ha^{-1} of N) was applied in equal three splits as top-dress at 30, 45 and 60 days after planting. Well-decomposed FYM was incorporated in the top 15 cm of soil about 10 days before

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sowing. Cloves of cv. Punjab Garlic-1 were sown at a 3-5 cm depth at a distance of 15 cm between rows and 7.5 cm between plants, in the second week of October. The first irrigation was applied immediately after planting and the second at 15 days after seeding to facilitate seedling establishment. Irrigation with 50 mm water was applied when cumulative pan evaporation after previous irrigation reached 31.3, 41.7 and 62.5 mm with an IW/PAN–E ratio of 1.6, 1.2, and 0.8, respectively. Total irrigation water input during the cropping season was recorded. Harvest was done at physiological maturity and yield recorded after bulbs had cured under shade for a week. Samples of bulb and tops were collected, dried to constant weight and analyzed for total N content using the steam distillation method (Keeney and Nelson, 1982) after digesting the plant material. Total N uptake was calculated by multiplying N content times dry weights of bulbs and tops. Crude protein content of onion bulbs was determined by multiplying percent total nitrogen by 6.25.

Results and Discussion

Total rainfall during the 2006-2007 (1st year) and 2007-2008 (2nd year) growing seasons was 159 and 89 mm, respectively. Average monthly maximum temperature varied from 19.5°C in January to 38.5°C in May 2007 and from 16.9°C in January to 36.5°C in May 2008. Average rainfall and pan evaporation during the cropping season (January to May) at Ludhiana was 134 and 741.8 mm, respectively, with maximum and minimum temperatures ranging from 5.6 to 38.7°C.

Irrigation Water Use

Irrigation water applied during the 2006-2007 (1st year) cropping season was 50, 40 & 30 cm and during 2007-2008 (2nd year) was 55, 45 and 35 cm, respectively, to provide the IW/PAN-E = 1.6, 1.2 and 0.8 ratios, respectively.

Garlic Bulb Yield

Farm yard manure @50 Mg ha^{-1} increased fresh bulb yield in both cropping seasons (Table 1). Zakari*et al.* (2014) also reported that organic manures significantly improved the garlic bulb yield. Garlic bulb yield was significantly higher during the 2nd cropping season, and that may be attributed to relatively lower temperature in the 2nd year (range 16.9 to 36.5°C) compared to 1st year (19.5 to 38.5°C). Optimum temperature for garlic has been reported to be 13-24°C (Black and Drost, 2010). Bulb yield increased with application of 125 kg ha^{-1} of N. However, the increase was significant only up to 100 kg ha^{-1} of N during 1st year (Table 1). Kilgori*et al.* (2007) and Tayel*et al.* (2010) reported the highest bulb yield with application of 120 kg ha^{-1} of N. Bulb yield of crop irrigated with IW/PAN-E = 1.6 and 1.2, were higher than that recorded with IW/PAN-E = 0.8. Increase in garlic bulb yield with increase in irrigation frequency from IW/PAN-E = 0.8 to 1.2 is in accordance with the previous findings (Ortega *et al.*, 2004; Mohamed *et al.*, 2009) that observed a positive response to irrigation frequency. The interaction between irrigation and nitrogen level indicated that plants receiving irrigation at IW/PAN-E = 0.8, bulb yield improved with increasing N up to 150 kg ha^{-1}, but improvement was observed only up to 125 kg ha^{-1} when irrigation was based on IW/PAN-E = 1.2 and 1.6 (Table 1). The interaction between FYM and N level indicated that with FYM, improvement of bulb yield (34%) was recorded up to 125 kg ha^{-1}, but without FYM, improvement of up to 58% occurred with up to 150 kg ha^{-1} of N (Table 1).

Regression equation for bulb yield (Y) and plant height (X_1) was: $Y=37.5 + 5.41\ X_1$ ($r^2 = 0.85$); bulb yield and number of cloves (X_2) was: $Y=-16.2 + 8.87\ X_2$ ($r^2 =0.80$), and bulb yield and weight/bulb (X_3) was: $Y=- 82.4 + 2.40\ X_3$ ($r^2 =0.62$). Bulb yield was significantly, and positively, correlated with numbers of cloves/bulb, bulb weight and plant height. Increases in bulb yield were mainly attributed to increases in number of cloves, bulb weight and plant height with FYM, N application and irrigation.

Nitrogen Uptake

Total N uptake was higher during the 1st year (Table 2) and increased with use of FYM. Improvement in N uptake was observed with fertilizer application up to 125 kg ha^{-1} of N. However, the improvement was 53% in the 1st year and 64%in the 2nd year. Optimum irrigation for total N uptake was at IW/PAN-E=1.2. The interaction between FYM and irrigation indicated that improvement in N uptake with increasing irrigation frequency was more with FYM.

Table 1. Garlic bulb yield (q ha^{-1}) as affected by FYM (Manure), irrigation and nitrogen levels

Manure	Irrigation	N levels, kg ha^{-1}									
		2006-07					2007-08				
		0	100	125	150	Mean	0	100	125	150	Mean
No FYM	1.6	54.5	84.6	87.7	86.8	78.4	65.5	96.5	105.3	105.9	93.3
	1.2	54.5	88.5	90.3	94.4	81.9	65.3	89.5	104.2	103.3	90.6
	0.8	63.8	81.0	80.3	89.6	78.7	60.2	85.3	93.1	93.7	83.1
	Mean	57.6	84.7	86.1	90.3	79.7	63.6	90.4	100.9	101.0	89.0
FYM	1.6	72.9	102.4	108.8	107.1	97.8	86.1	102.2	109.5	107.5	101.3
	1.2	71.6	101.3	105.6	101.7	95.1	87.0	102.8	110.9	110.8	102.9
	0.8	72.1	98.3	93.5	100.4	91.1	84.2	98.9	107.0	107.7	99.4
	Mean	72.2	100.7	102.6	103.1	94.6	85.8	101.3	109.1	108.7	101.2
Mean	Year	2006-07= 87.2; 2007-08= 95.1									
	Manure	No FYM = 84.3; FYM = 97.9									
	Irrigation	0.8= 88.1; 1.2= 92.7; 1.6= 92.8									
	Nitrogen	0= 69.8; 100= 94.3; 125= 99.7; 150= 100.8									
LSD (p=0.05)	Year= 2.37; Manure= 2.41; Irrigation = 2.14;Nitrogen= 2.44; Year × Nitrogen =3.45; Manure × Nitrogen=3.45; Irrigation × Nitrogen =4.23; Year × Manure × Irrigation= 4.29; Year × Manure × Nitrogen= 4.88										

Table 2. Effect of manure, irrigation and nitrogen levels on total N uptake (kg ha^{-1}) by garlic

Manure	Irrigation	N levels, kg ha^{-1}									
		2006-07					2007-08				
		0	100	125	150	Mean	0	100	125	150	Mean
	1.6	66.5	110.5	115.7	119.1	103.0	55.2	85.5	98.7	99.8	84.8
No FYM	1.2	65.8	117.2	125.2	119.3	106.9	58.8	84.3	99.8	101.8	86.2
	0.8	69.8	102.1	105.4	110.4	96.9	52.3	76.9	92.2	96.4	79.5
	Mean	67.4	109.9	115.4	116.3	102.3	55.4	82.2	96.9	99.3	83.5
	1.6	103.6	132.8	143.1	145.7	131.3	76.2	110.8	121.2	125.2	108.4
FYM	1.2	94.9	134.6	136.5	138.6	126.2	75.9	107.5	118.1	127.9	107.4
	0.8	85.4	112.5	117.5	122.5	109.5	74.2	102.6	112.0	115.2	101.0
	Mean	94.6	126.6	132.4	135.6	122.3	75.4	107.0	117.1	122.8	105.6
Mean	Year	2006-07= 112.3; 2007-08= 94.6									
	Manure	No FYM = 92.9; FYM = 113.9									
	Irrigation	0.8= 96.7; 1.2= 106.7; 1.6= 106.9									
	Nitrogen	0= 73.2; 100= 106.4; 125= 115.4; 150= 118.5									
LSD (p=0.05)	Year= 4.21; Manure= 3.39; Irrigation = 2.63;Nitrogen= 3.22; Year × Irrigation =3.72; Year × Nitrogen =4.56; Manure × Irrigation =3.72; ; Year × Manure × Irrigation= 5.26										

Table 3. Effect of manure, irrigation and nitrogen levels on crude protein content (%) of garlic

Manure	Irrigation	N levels, kg ha^{-1}									
		2006-07					2007-08				
		0	100	125	150	Mean	0	100	125	150	Mean
No FYM	1.6	15.5	16.0	16.9	17.9	16.6	14.5	15.8	16.4	16.6	15.8
	1.2	15.1	18.1	18.6	17.2	17.3	15.7	16.8	16.8	16.9	16.6
	0.8	13.3	16.1	18.0	17.4	16.2	15.1	15.7	17.4	18.3	16.6
	Mean	14.6	16.7	17.8	17.5	16.7	15.1	16.1	16.9	17.3	16.3
FYM	1.6	18.1	16.2	16.9	19.1	17.6	15.4	19.2	19.7	20.9	18.8
	1.2	16.6	17.1	17.3	18.1	17.3	15.1	18.4	18.9	20.4	18.2
	0.8	15.3	15.6	18.1	17.0	16.5	15.1	18.5	18.7	18.9	17.8
	Mean	16.7	16.3	17.4	18.1	17.1	15.2	18.7	19.1	20.1	18.3
Mean	Year	2006-07= 16.9; 2007-08= 17.3									
	Manure	No FYM = 16.5; FYM = 17.7									
	Irrigation	0.8= 16.8; 1.2= 17.3; 1.6= 17.2									
	Nitrogen	0= 15.5; 100= 17.1; 125= 17.8; 150= 18.2									
LSD (p=0.05)	Manure= 0.49; Irrigation = 0.35;Nitrogen= 0.35; Year × Manure=0.7; Year × Nitrogen =0.49; Manure × Irrigation =0.49; Irrigation × Nitrogen=0.6; Year × Manure × Nitrogen = 0.7; Year × Irrigation × Nitrogen=0.85; Manure × Irrigation × Nitrogen=0.85										

This improvement in N uptake with irrigation frequency in FYM was more during 1st year.

Crude Protein Content

Crude protein content of garlic bulb significantly improved from 16.5% without FYM to 17.7% with FYM (Table 3). Increases in bulb protein content occurred with each increment of N upto 150 kg ha^{-1} of N. Without FYM protein content increased with N application up-to 125 kg ha^{-1} in both the years. With FYM crude protein content increased up to 150 kg ha^{-1} of N. No improvement in protein content occurred beyond 125 kg ha^{-1} of N without FYM treatment may be due to other nutrients becoming limiting at 150 kg ha^{-1} of N; FYM incorporation likely provided balanced nutrition even at the highest N level. Bertoni*et al.* (1992) reported a decrease in nitrogen content of bulbs with early nitrogen deprivation in pots receiving fertigation. The interaction indicated that increases in crude protein with increase in irrigation frequency occurred in plants treated with FYM; but without FYM crude protein content increased with increases in irrigation frequency from IW/PAN-E=0.8 to 1.2 and then declined at IW/PAN-E=1.6. Besides providing balanced nutrition, incorporation of FYM improves water retention in the soil profile (Aggarwal *et al.*, 1995). Use of FYM likely retains greater amounts of water that facilitates N adsorption and leads to improved crude protein content. Low water retention in no FYM plots may result in deep percolation losses of nitrogen with frequent irrigation that might be unavailable for uptake by shallow root system of garlic.Crude protein content increased upto 150 kg ha^{-1} of N in frequently irrigated garlic. Increase in protein content of garlic with N level was more with restricted irrigation. With more frequent irrigation, increase in crude protein content with N was higher in the 2nd year. In manure plots, crude protein content improved up-to 150 kg ha^{-1} of N with frequent irrigation. However, restricted irrigation in FYM and at all irrigation levels in no FYM, the crude protein content improved only up-to 125 kg ha^{-1} of N.

Bulb Characteristics

Bulb circumference was larger with use of FYM (Table 4). With fertilizer N up to 100 kg ha^{-1}, bulb size increased. Average bulb weight was higher when FYM was used (Table 4). Bulb weight increased as fertilizer N increased. Bulb weight improved with increase in irrigation frequency upto IW/PAN-E =1.2. This observation agrees with Mohamed *et al.* (2009) who reported higher bulb weight, bulb diameter and total yield of garlic with irrigation at 15 days interval compared to more and less frequent irrigation (10, 20 or 25 days interval).

Table 4. Effect of manure, irrigation and nitrogen levels on circumference, bulb weight and number of cloves

Manure	Irrigation	N levels, kg ha^{-1}				Mean
		0	100	125	150	
Circumference (cm)						
No FYM	1.6	10.7	11.3	11.3	11.7	11.3
	1.2	10.6	11.3	11.7	11.0	11.2
	0.8	9.8	10.6	10.8	11.1	10.6
	Mean	10.4	11.1	11.3	11.3	
FYM	1.6	11.9	12.3	12.4	12.4	12.3
	1.2	10.8	12.5	12.0	11.9	11.8
	0.8	10.5	12.0	12.3	12.8	11.9
	Mean	11.1	12.3	12.2	12.4	
Mean	Manure	No M= 11.0; M= 12.0				
	Irrigation	0.8= 11.3; 1.2= 11.5; 1.6= 11.8				
	Nitrogen	0= 10.7; 100= 11.7; 125= 11.8; 150= 11.8				
LSD (p=0.05)	Manure= 0.6;Nitrogen= 0.48					
Bulb weight (g/bulb)						
No FYM	1.6	10.2	11.4	12.1	13.2	11.7
	1.2	9.6	11.6	12.8	12.4	11.6
	0.8	8.4	10.2	11.0	12.2	10.5
	Mean	9.4	11.1	12.0	12.6	
FYM	1.6	12.6	13.5	14.4	14.3	13.7
	1.2	12.0	13.1	13.3	13.6	13.0
	0.8	10.4	12.5	12.9	12.8	12.2
	Mean	11.7	13.0	13.5	13.6	
Mean	Manure	No M= 11.3; M= 13.0				
	Irrigation	0.8= 11.4; 1.2= 12.3; 1.6= 12.7				
	Nitrogen	0= 10.5; 100= 12.1; 125= 12.8; 150= 13.1				
LSD (p=0.05)	Manure= 1.44; Irrigation = 0.7; Nitrogen = 0.75					
		Number of cloves per bulb				
No FYM	1.6	19.6	23.7	23.0	23.4	22.4
	1.2	20.3	22.2	22.9	24.1	22.4
	0.8	17.3	23.1	23.0	24.4	22.0
	Mean	19.1	23.0	23.0	24.0	
FYM	1.6	23.4	26.0	27.3	27.5	26.1
	1.2	22.1	25.6	26.9	26.7	25.3
	0.8	21.8	24.5	26.1	26.3	24.7
	Mean	22.4	25.4	26.8	26.8	
Mean	Manure	No M= 22.3; M= 25.4				
	Irrigation	0.8= 23.4; 1.2= 23.9; 1.6= 24.3				
	Nitrogen	0= 20.8; 100= 24.2; 125= 24.9; 150= 25.4				
LSD (p=0.05)	Manure= 1.62; Nitrogen=1.2					

of garlic

Table 5. Effect of manure, irrigation and nitrogen levels on irrigation water productivity (kg ha^{-1} mm^{-1}) of garlic (Average of 2 year)

Manure	Irrigation	N levels, kg ha^{-1}				Mean
		0	100	125	150	
No FYM	1.6	11.4	17.2	18.3	18.3	16.3
	1.2	14.1	21.0	22.9	23.3	20.3
	0.8	19.2	25.7	26.7	28.3	25.0
	Mean	14.9	21.3	22.6	23.3	
FYM	1.6	15.1	19.5	20.8	20.5	19.0
	1.2	18.6	24.1	25.5	25.0	23.3
	0.8	24.0	30.5	30.9	32.1	29.4
	Mean	19.2	24.7	25.7	25.9	
Mean	Year	2006-07= 22.7; 2007-08= 21.8				
	Manure	No M= 20.5; M= 23.9				
	Irrigation	0.8= 27.2; 1.2= 21.8; 1.6= 17.6				
	Nitrogen	0= 17.1; 100= 23.0; 125= 24.2; 150= 24.6				
LSD (p=0.05)	Year=0.73; Manure=0.56; Irrigation=0.58 ; Nitrogen=0.60; Year × Irrigation =0.82; Year × Nitrogen=0.84; Manure × Irrigation= 0.82; Manure × Nitrogen=0.84; Irrigation × Nitrogen=1.03; Year × Manure × Irrigation=1.15; Year × Manure × Nitrogen=1.19					

Hanson *et al.* (2002) reported an optimum irrigation schedule at one week interval to increase garlic yield. Use of FYM increased numbers of cloves/bulb. Numbers of cloves/bulb increased as nitrogen level increased (Table 4). Suthar (2009) reported that a combination of organic and inorganic fertilizers improved bulb weight and number of cloves/bulb.

Irrigation Water Use Efficiency

Use of FYM improved water use efficiency by 3.4 kg ha^{-1} mm^{-1} (Table 5). Irrigation water use efficiency without FYM was 20.5 kg ha^{-1} mm^{-1} that increased to 23.9 kg ha^{-1} mm^{-1} with FYM. Increased N application increased water use efficiency up to 125 kg ha^{-1} of Nwhen irrigation was IW/PAN-E=1.2 and 1.6, and in plots receiving irrigation at IW/PAN-E=0.8 improvement occurred up to 150 kg ha^{-1} of N. Mohammad and Zuraiqui (2003) reported increased water use efficiency in garlic by addition of fertilizer-N. Water use efficiency progressively decreased with increase in irrigation water input. The amount of IWUE was 17.7, 21.8 and 27.1 kg ha^{-1} mm^{-1}, respectively with IW/PAN-E=1.6, 1.2 and 0.8. Sharmasarkar*et al.* (2001) reported higher water use efficiency in sugar-beets with drip irrigation than flood irrigation and among the drip systems; WUE was highest with irrigation at 20% depletion of field capacity compared to 35 and 50% depletion. The findings of Tayel*et al.* (2010) for garlic and Sekhon*et al.* (2008) for chilli also reported decrease in irrigation water use efficiency with increase in irrigation water input. Improvement in IWUE with FYM was 17.7% under restricted irrigation compared to 12.9% with IW/PAN-E=1.2. The optimum irrigation schedulewas IW/PAN-E=1.2 and optimum N fertilizer requirement of garlic was 125 kg ha^{-1}. Bulb yield and water use efficiency increased up to 150 kg ha^{-1} of N with irrigation at IW/PAN-E=0.8 irrespective of FYM application. Water productivity was highest with IW/PAN-E=0.8. Although FYM alone was beneficial for bulb size, number of cloves, crude protein content, bulb yield, water use efficiency and total N uptake, the combined use of FYM and synthetic N fertilizer further improved all these parameters.

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