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PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Pakistan Journal of Biological Sciences 10 (13): 2219-2224, 2007
ISSN 1028-8880

Evaluating Yield Quality and Quantity of Garlic as Affected by Different Farming Systems and Garlic Clones

R. Mirzaei, H. Liaghati and A. Mahdavi Damghani
Department of Agroecology, Environmental Sciences Research Institute,
Shahid Beheshti University, Tehran, Iran

Abstract: In order to study the effects of different farming systems and garlic (*Allium sativum* L.) clones on yield quality and quantity of garlic, an experiment was conducted with split plot arrangement with three completely randomized blockes in the 2005 growing season at the experimental research station of Shahid Beheshti University at Zirab, north of Iran. Two factors were involved in the experiment: farming systems in three levels (intensive, conventional and organic farming), as main plots and garlic clones in three levels (Atoo, Hamedani and Khorassani) as sub-plots. The studied factors in this experiment consisted of leaf number, LAI, stem height and diameter, bulb yield, weight of bulbs, number of cloves, weight of cloves and level of allicin. Results showed that the farming systems had significant effect ($p \le 0.05$) on LAI, number of plant and bulb yield, but the effect on the other factors was not significant. The highest and lowest bulb yields were obtained in intensive (9.5 ton ha^{-1}) and organic (7.4 ton ha^{-1}) systems, respectively. All of the top factors were significantly ($p \le 0.01$) affected by garlic clones. Maximum and minimum yields were obtained from Hamedani, Atoo (9.2 ton ha^{-1}) and Virani (7.1 ton ha^{-1}) clones, respectively. Level of allicin was not significantly affected by farming systems but, differences among garlic clones were significant. Maximum and minimum allicin yields were obtained from Hamedan (5.96 mg g^{-1}) and Virani (4.52 mg g^{-1}) clones, respectively. As a result, however, organic farming systems can not influence the yield in short term, but can increase it by applying crop rotation, use of organic fertilizer and cover crops in the long term.

Key words: Garlic, intensive, traditional, krganic farming, allicin

INTRODUCTION

Garlic is one of most important bulb crops which have been cultivated since 3000 B.C. in the Egypt (Ipek and Simon, 2002). Garlic production is in the second rate in the onion family after onion. It is widely used as a spice and has higher nutrition value than other crops of onion crops (Bachmann, 2001; Eagling and Sterling, 2000). Many researchers investigated the nature of the volatile compounds in garlic which is known to possess many beneficial activity for human health (Briggs *et al*., 2000). Garlic chemical contents divide to two sulfur and non-sulfur groups. Garlic medicinal characters are mainly because of allicin, a sulfur chemical composition (Schulz *et al*., 1998). Allicin (diallylthiosulfinate) is the best known active compound of garlicand it represents about 70% of the overall thiosulfinates present or formed upon crushing the cloves. Allicin is known to possess a vast variety of biological effects. Its antimicrobial, anti-inflammatory, antithrombotic, anticancer and antiatherosclerotic activities, as well as the capacity to lower serum lipid levels and ocular pressure, were reported (Lawson, 1998). Most of these effects can be related to its strong SH-modifying and antioxidant properties (Rabinkov *et al*., 1998). Garlic extracts and the majority of commercial garlic food supplements, such as tablets and capsules containing garlic powder, are based on either allicin content or on the potential to produce allicin (Lawson and Wang, 2001). Content of allicin and other sulfur chemicals in garlic vary extensively depends on several factors. For medicinal application, higher rates of allicin are more favorable (Huchette *et al*., 2004).

Most vegetables are now cultivated conventionally worldwide, but attempts has done to apply integrated pest management and low input production systems in these crops and remarkable successes has been achieved (Greer and Diver, 2000). The intensification of agricultural production over the past 60 years and the subsequent increase in global synthetic N inputs have resulted in substantial N pollution and ecological damage (Alcamo *et al*., 2005). The primary source of N pollution comes from N-based agricultural fertilizers, whose use is forecasted to double or almost triple by 2050 (Tilman *et al*., 2001). The application of N fertilizers has

Corresponding Author: Reza Mirzaei, Environmental Sciences Research Institute, Shahid Beheshti University, Evin Street Tehran, Iran Tel: +98 21 2990 2867 Fax: +98 21 2243 1973

resulted in N leakage from agricultural systems into groundwater, rivers, coastal waters and the atmosphere. Nitrate leaching and N_2O emissions from agricultural soils are recognized as significant environmental threats by scientists, environmental groups and agricultural policymakers (Environmental Defense Fund, 2001). Nitrate leaching and runoff into rivers and estuarine ecosystems are responsible for algal blooms and eutrophication and also pose a public health risk (Beman *et al*., 2005). For example, 9% of U.S. domestic wells sampled during 1993-2000 had nitrate concentrations exceeding the U.S. Environmental Protection Agency's (EPA) maximum contaminant level of N 10 mg L^{-1} (Nolan *et al*., 2002). There has been poor development of rational fertilizer recommendations in the areas with rapidly expanding production systems. So, excessive N fertilizer application is therefore very common, especially in intensive production areas and might be expected to lead to nitrate pollution of groundwater (Ju *et al*., 2006). In a European study, the nitrate concentration in groundwater samples from 22% of the agricultural area exceeded the threshold recommended by the World Health Organization (50 mg NO_3 L^{-1}) for drinking water (Laegreid *et al*., 1999).

Consumers are becoming increasingly concerned about how, where and when foods are produced. This has led to an increased consumer interest in organically grown vegetables. cultivated garlics in Northern Iran are often produced as traditional system in which based on local farmers, chemical fertilizer was applied like intensive system in soil. In this system, it is not realistic to use organic farming method (organic fertilizer, crop rotation, crop residue or crop diversity) to increase the sustainability of the production. This has led to problems with nutrient supply, balance and losses.

In Iran, application of chemical pesticide and fertilizers in agroecosystems has been increased during recent decades; so there are many questions on health and safety of agricultural products. Conventional agriculture has resulted environmental pollution and deterioration globally and diminished biodiversity, ecosystem balance and natural resources. Application of chemical pesticides and fertilizers has further costs than economic one including human and environment health. Introducing alternative and especially, organic farming systems is a necessity to solve above mentioned problems (Koocheki *et al*., 1997).

Despite of some beliefs, low input and organic systems are generally producing same yield as conventional systems. Yield decrease due to organic management practices has usually reported about 10% depending crop species and location; for example, organic wheat yield in England and Canada is respectively 11 and 6% less than conventional wheat. Reports in US also showed that the yield loss due to organic farming is less than 5% in maize, soybean, wheat and tomato. However, lower input costs because of their lower (or no) application rate than conventional farming systems as well as premium price of organic crops has compensated yield losses and made organic farming economically viable (Halbery *et al*., 1994). Also, in a study of conventional, low input and organic systems, yield of tomato, safflower, maize and bean in organic and low input systems were comparable with conventional systems (Clark *et al*., 1999a). In other study, maize and soybean produced same or higher yield in organic in comparison with conventional systems (Welsh, 1999).

The effect of farming systems on qualitative and quantitative characters of garlic has not been studied widely. Pereira and Fornazier (1995) reported that applying 20 ton ha^{-1} compost as an alternative for chemical fertilizer increased garlic yield and decreased storage losses and pest and disease damages. Results of Cho *et al*. (1994) showed that poultry manure as fertilizer increased the concentration of sulphate and pyruvic acid which are main metabolites of allicin production. The objective of this study is to evaluate the yield qualitative and quantitative characters of three Iranian garlic clones under different agricultural management practices.

MATERIALS AND METHODS

The experiment was conducted in 2004-2005 growing season in research station of Shahid Beheshti University in Zirab, north of Iran. Annual rainfall of the location is 700 mm; mean temperature is 15.6°C and the altitude is 1200 m. Soil samples was taken from 0-30 cm depth of the field soil before applying treatments (Table 1). Experimental design was split plot with four completely randomized blocks. Treatments were farming system as main plot with 3 levels.

- Intensive system in which weeds were controlled before planting by Roundup; chemical fertilizer was applied based on soil test (150 kg ha^{-1} super phosphate triple applied in the beginning of growing season plus 100 kg ha^{-1} urea which applied in three equal parts at the beginning of the growing season, time of first weeding on March 5th and one month before harvest); garlic fly was controlled by 2 diazinon (20%) spraying and garlic rust was controlled by three guzation spraying;
- Traditional or conventional system in which based on local farmers, chemical fertilizer was applied like intensive system plus another 100 kg ha^{-1} potash applied one month before harvest. No chemical

Table 1: Soil chemical and physical characteristics in the studying area

Absorbable K (ppm)	Absorbable P (ppm)	Total N (%)	Organic carbon (%)	Organic matter (%)	TNV (%)	Total saturation pH (sp. %)	Electric conductivity ($EC10^{-3}$)	Saturation percent (cm)	Soil depth
410	5.83	0.21	2.02	2.86	9	7.8	0.6	73	0-30

treatment was applied for pest and disease control. Weeds were controlled by hand weeding twice during growing season;

- Organic system in which no chemical fertilizer or pesticide was applied. Crop residues of last year remained on the soil surface. 25 ton ha^{-1} Cattle farmyard manure was applied as nitrogen fertilizer based on soil test two weeks before planting. Rice residue was distributed on the planting rows after seeding garlic to prevent weed germination and growth,

and garlic clones as sub-plot in three levels including three Iranian clones named Atoo (the land race of local farmers in Zirab), Hamedani and Virani. Garlic was planted on October 28th 2004. Each plot (3-4 m) consisted of 12 rows. Two rows of each plot selected on the harvest and 15 plants were taken and sent to laboratory to record parameters including mean garlic and clove weight, number of clove per garlic, leaf number and plant height. Crop yield was determined from plants of these two rows after deleting marginal effect of the rows. Ten plants were selected from each row to determine allicin concentration by HPLC (High Performance Liquid Chromatography) method. Data were analyzed by Excel, SAS (SAS Institute, 2000) and MSTAT packages.

RESULTS AND DISCUSSION

Yield and yield components: Results of analysis of variances of yield and yield components are shown on. The effects of farming systems and garlic clones on garlic can be mentioned as below Table 2.

Garlic yield: Effects of farming system and garlic clone on yield were significant ($p<0.01$ and 0.05, respectively). Interaction of farming system by garlic clone was also significant ($p<0.05$). The highest garlic yields were obtained in intensive (9.5 ton ha^{-1}) and conventional (8.8 ton ha^{-1}) farming systems, though their difference was not significant. In garlic clones, Hamedani and Atoo produced the highest yields (9.3 and 9.2 ton ha^{-1}, respectively, Table 3).

Results showed that interaction of farming system and garlic clone on yield was significant; the highest yields were achieved in Hamedani clone in intensive and Atoo clone in organic farming systems (10.98 and 9.97 ton ha^{-1}, respectively). In the other hand, Virani clone in organic farming system produced the lowest yield (5.97 ton ha^{-1}, Table 4). Reducing yield in organic farming has reported by other researchers. Results of a study of factors limiting tomato yield in different farming systems showed that tomato yield decreased in organic farming systems, especially in first years of converting to organic farming. In this study, nitrogen, water and weed had significantly affected tomato yield, but their effect had a significant correlation with farming systems (Clark *et al*., 1999b). Results indicated that nitrogen supply is the most limiting factor of yield in organic systems, while water supply had the most important role in conventional fields. Poudel *et al*. (2002) reported yield reduction of maize and tomato in organic and low input systems during first years, though after 5 years, differences of various systems yield became insignificant.

Bulb weight, clove weight and number per bulb: Effect of garlic clone on mean bulb weight was significant ($p<0.01$), but farming system and interaction of garlic clone by farming system had no significant effects on mean bulb weight. In clones, Hamedani and Atoo had the highest mean bulb weight (26.69 and 24.97 g, respectively). Effect of garlic clone on number of cloves per bulb was also significant ($p<0.01$); however, effects of farming system and its interaction by garlic clone on it were not significant. Virani (11.43) and Atoo (11.38) had the highest number of cloves per bulb. The effect of garlic clone on mean clove weight was significant and Hamedani produced the highest clove weight (2.97 g, Table 2).

LAI, leaf number, stem height and diameter: The greatest LAI was recorded in intensive and conventional farming systems (0.8, $p<0.05$). Effect of garlic clone on LAI was significant and Hamedani and Atoo produced the greatest LAI (0.8, $p<0.01$). Interaction of farming system and garlic clone on LAI was significant ($p<0.01$); the greatest and lowest LAI was recorded in Hamedani clone in intensive (8.9) and Virani clone in organic (0.6) farming systems, respectively (Table 2, Table 3).

Effect of farming system and interaction of farming system by garlic clone on leaf number and stem height and diameter were not significant; effect of garlic clone, however, on these parameters was significant ($p<0.01$). Results of mean comparison of these parameters are shown in Table 2. Hamedani clone had the highest leaf number and stem diameter and the lowest stem height (Table 2, Table 5).

Table 2: Analysis of variance of studied characteristics of garlic

	MS												
df	Allicin mg g^{-1}	Weed biomass g m^{-2}	Weed composition plant m^{-2}	Weed density plant m^{-2}	Average weight of clove	Average weight of bulb	No. of clove per bulb	No. of plant m^{-2}	LAI	Bulb yield (ton ha^{-1})	Stem diameter (mm)	Stem height	Leaf number
3	0.0ns	0.25ns	1.287ns	0.769ns	0.13ns	7.51ns	0.388ns	6.917ns	0.008ns	4164ns	1.514ns	2.047ns	0.143ns
2	0.11ns	21204ns**	73.361ns**	1219.083**	0.172ns	19.029ns	0.917ns	66.694*	0.068*	14348*	3.685ns	2.3ns	0.652ns
6	0.05ns	3.806ns	0.62ns	0.713ns	0.15ns	13.873ns	1.168ns	18.583ns	0.01ns	13576ns	1.136ns	4.537ns	0.168ns
2	5.64 **	1.028ns	0.361ns	3.083ns	3.892**	94.116**	21.247**	53.861**	0.098**	179808**	18.594**	96.673**	14.799**
	0.007ns	7.986ns	1.278ns	1.417ns	0.226ns	6.334ns	0.579ns	12361ns	0.006ns**	16058*	0.404ns	0.69ns	0.451ns
4	0.05ns	6.926ns	1.009ns	2.231ns	0.089ns	4.712ns	0.727ns	5.417ns	0.001ns	4996ns	0.472ns	1.504ns	0.166ns
18	4.56	3.45	17.14	11.42	12.68	8.94	8.02	6.62	4.58	8.26	8.75	5.97	5.29

ns = Non-Significant, *Significant at 5% level ($p<0.05$), **Significant at 1% level ($p<0.01$)

Table 3: Mean comparison garlic bulb yield and leaf area index (LAI) in different farming systems and garlic clones

Treatments		Crop yield (ton ha^{-1})	LAI
Farming system	9.5a	9.5a	0.85a
	8.8a	8.8a	0.8a
	7.4b	7.4b	0.7b
Garlic clones	9.2a*	9.2a*	0.83a
	9.3a	9.3a	0.84a
	7.1b	7.1b	0.68b

Means within columns followed by the same letter are not significantly different (Duncan LSD, $p<0.05$, * $p<0.01$)

Table 4: Interaction of farming system and garlic clone on garlic bulb yield

	Garlic clones		
Farming system	Atoo	Hamedani	Virani
Intensive	9.6bc	11:00a	7.9 de
Traditional	10ab	8.9cd	7.6e
Organic	8.1de	8de	6f

Means within columns followed by the same letter are not significantly different (Duncan LSD, $p<0.05$)

Table 5: Measures of leaf number, stem height, diameter and allicin concentration in different garlic clones

Treatments		No. of leaf	Stem height (cm)	Stem diameter (mm)	Allicin concentration (mg g^{-1})
Garlic Clones	Atoo	6.9c	23a	7.26b	4.7b
	Hamedani	9a	17.44c	9.28a	6a
	Virani	7.3b	21.19b	7.02b	4.5b

Means within columns followed by the same letter are not significantly different (Duncan LSD, $p<0.01$)

Table 6: Weed density, composition (weed species per m^2) and weed biomass in different farming systems

Treatments		Weed density (Plant m^{-2})	Weed composition	Weed biomass (g m^{-2})
Farming system	Intensive	5.4c	4c	41.9c
	Traditional	24.5a	8.7a	123.2a
	Organic	9.3b	4.9b	63.8b

Means within columns followed by the same letter are not significantly different (Duncan LSD, $p<0.01$)

Weed density, composition and biomass: Farming system had significant effect on weed density, but the effects of garlic clone and interaction of farming system by garlic cline on weed density were not significant. The highest weed density was recorded in conventional system (24.5 weed m^{-2}, Table 2, Table 6). Weed species also affected by farming system significantly ($p<0.05$) and the highest weed species diversity was recorded in conventional farming system (8.67 species m^{-2}, Table 2, Table 6).

Farming system had a significant ($p<0.05$) effect on weed biomass, but the effects of garlic clone and interaction of farming system and garlic clone on weed biomass were not significant. The highest weed biomass was recorded in conventional farming system (132.2 g m^{-2}, Table 6). Other research showed that converting to organic farming results in increasing weed diversity and biomass (Clark *et al*., 1999b), but some management practices such as remaining crop residue on the soil surface and applying cover crop could minimize weed problems in these systems, especially in organic vegetable production (Hutchinson and McGiffen, 2000 and Ngouajio and McGiffen, 2001). In the present study, intensive farming system reduced number and diversity of weeds by applying chemical treatments and organic system decreased weeds biomass and diversity through covering soil surface by crop residues which prevented weed germination and growth and so mitigated an effect like intensive systems on weed dynamic and biomass.

Allicin concentration: Effect of garlic clone on allicin concentration was significant ($p<0.01$); however, effects of interaction of treatments were not significant. Allicin concentration was not affected by farming system, but the highest concentration of allicin was recorded in Hamedani (5.96 mg g^{-1}, Table 5).

Concentration of sulfur compounds and allicin in garlic varies extensively and depends to several factors. In the pharmacological industries, garlic varieties with high amount of sulfur compounds and allicin are more favorable (Huchette *et al*., 2004). Allicin concentration in garlic is affected by plant genetic and management practices. Results of studies show that application of compost increases allicin concentration (Pereira and Fornazier, 1995). Cho *et al*. (1994) showed that applying manure increased allicin metabolites. Allicin concentration of Atoo and Virani clones were acceptable for food and pharmacological industries.

CONCLUSIONS

In garlic clones, Atoo and Hamedani produced the highest and Virani produced the lowest bulb yield. Clones and cultivars in general express different responses to climate, soil characters and pests and diseases. Weather and climate as well as pest and diseases seem to have higher impacts on clones yield in the present study. Hamedani and Atoo had same high yields despite growing in different climate than their adapted climate, but as their climatic needs was more similar in the Zirab than Virani and also Hamedani's more tolerance to pest and diseases, they could produce acceptable yields. It seems that failure to resist pests and disease is the main factor preventing Virani to produce standard yield.

Results of present study indicate that soil fertility seems to be most important limiting factor for developing garlic organic farming. Farmyard manure could not provide nutritional demands of garlic crop. Allicin concentration was also affected more by genetic and management practices. Therefore, improving crop management through applying organic fertilizers, cover crop and compost as well as crop rotation which enhance soil fertility, will result in garlic quantitative and qualitative yield. It seems that although organic farming systems can not influence crop yield in short term, but can increase it in the long term as crop management improves and soil fertility establishes sustainably.

ACKNOWLEDGMENTS

We would like to thank Shahid Beheshti University for providing the costs of the research according to research contract No. 600/5028. Thanks also go to Majid Rostami and Mehrangiz Karimi for their help with production, data collection and analytical aspects of the project. Appreciation is expressed to professor Alireza Kochaki and Dr. Eskandar Zand for their supports and assistances during the study. Thanks also to Keyvan Kamel for the HPLC analysis.

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