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Article

Between-row spacing and local accession on the yield and quality of garlic

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Abstract

Garlic is primarily grown for its cloves used mostly as a food flavoring condiment. Previous studies carried out on plant density indicate its direct influence on yield. Plant density depends on the genotype, environmental factors, cultural practices, etc. This study was established to determine the effects of different between-row spacing on growth, yield, and quality of four local accession of garlic. It was laid out on two-factorial Randomized Complete Block Design with three replications during two years. Four local accession of garlic (Langroud, Tarom, Tabriz and Hamedan) were culture in three between-rows spacing (15, 25 and 35 cm) during two years. The results of two cultivated years were different. Plant density changed when garlic cultured with different between row spacing. In present research plant yield increased when the lower between row spacing and high plant density were used but the yield improvement occurring at increased plant stand is offset by the reduction in bulb size and some quality indices such as total phenol and antioxidant which severely affects quality and market value, when garlic is produced for fresh market.

Keywords: harvesting index, bulb yield, antioxidant capacity, total phenol

Espaçamento entre linhas e acessos locais na produtividade e qualidade do alho

Resumo

O alho é cultivado principalmente por seus dentes e é usado principalmente como um condimento. Estudos anteriores realizados sobre densidade de plantas indicam a sua influência direta sobre o rendimento. A densidade de plantas depende do genótipo, fatores ambientais, práticas culturais, etc. Este estudo foi estabelecido para determinar os efeitos de diferentes espaçamentos entre linhas no crescimento, rendimento e qualidade de quatro acessos locais de alho. O delineamento foi blocos casualizados em esquema fatorial, com três repetições, durante dois anos. Quatro acessos locais de alho (Langroud, Tarom, Tabriz e Hamedan) foram cultivados em três espaçamentos entre linhas (15, 25 e 35 cm) durante dois anos. Os resultados de dois anos cultivados foram diferentes. A densidade de plantas foi alterada quando o alho foi cultivado em diferentes espaçamentos entre linhas. Na presente pesquisa a produtividade por planta aumentou quando o espaçamento entre linhas foi inferior e alta densidade de plantas foram utilizadas, mas a melhoria de rendimento ocorre melhor estande de plantas e redução no tamanho do bulbo e de alguns índices de qualidade, tais como fenóis totais e antioxidantes que afetam severamente a qualidade e valor de mercado, quando o alho é produzido para o mercado *in natura*.

Palavras-chave: índice de colheita, produção de bulbos, capacidade antioxidante, fenóis totais

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Introduction

Garlic is primarily grown for its cloves used mostly as a food flavoring condiment. But many producers in northern Iran cultivated this crop for its leaves to prepare different local dishes (Olfati et al., 2010). Garlic has the high contents of organosulphur antioxidant compounds (Abdel-Wahhab et al., 2012).

Previous studies carried out on plant density indicate its direct influence on different crop yield (Castille et al., 1996; Wang et al., 1997; Castellanos et al., 2004; Lima et al., 2012; Ibrahim, 2012; Zhang et al., 2012; Souza et al. 2013; Nyakudya and Stroosnijder, 2014). They indicated that although plant yield increased when the higher plant density were used but the yield improvement occurring at increased plant stand is offset by the reduction in bulb size which severely affects quality and market value, when garlic is produced for fresh market (Castellanos et al., 2004). Castillo et al. (1996) recommended handling plant densities from 140000 to 180000 plants/ha to ensure a good bulb diameter.

The photosynthetic apparatus performs photosynthesis, which involves the production of organic matter (carbohydrates, protein and fats) in organic or conventional production systems. The leaves are the most important part of the plant for photosynthetic activity. Photosynthesis depends on a large number of factors. Foremost among these is the chlorophyll content of the leaves, followed by the leaf surface area, which determines how much sunlight, will be absorbed by the plant. In addition, photosynthesis depends on the genotype (Moracevic, 2011). Leaf number per plant, leaf area per plant, and leaf area index (LAI), which represents a crop's total leaf area per unit area (m^2/ha) are the most important factors in plant photosynthesis ability. Garlic develops 8 to 14 leaves. The photosynthetic apparatus of a cultivated plant can be acted upon via plant density (leaf number per unit area). Plant density depends on the genotype, environmental factors, cultural practices, etc. It should be noted that a thinner stand promotes the expression of an individual plant's potential, whereas denser stands are conducive to a greater expression of the plants' collective potential (crop potential). This has been noted by many authors, especially those working in the field of plant physiology. Many researchers have studied the effects of stand density on garlic. Data are also available for leaf number per plant, leaf area, and leaf area index. Studies have shown that there is no single, universal plant density that would be optimal for a garlic crop regardless of the soil and climatic conditions it is grown under.

Llosas and Fernandez (1984) argue that the ideal stand density for garlic is about 800,000 plants/ha. They note that this particular density is very high, but that it only negatively affects bulb uniformity. According to Lewis et al. (1995), garlic responds best to a plant population of 330,000 individuals/ha, as this density allows the plant in general and the leaves in particular to develop optimally. Results obtained by Muro et al. (2000) indicate that garlic leaf parameters (leaf number per plant, leaf area and leaf mass) reach their maximum values three weeks before the bulbs are harvested. Ahmad and Iqbal (2002) studied plant densities of up to 2,000,000 plants/ha, but they achieved the best results with stands of moderate density (around 600,000 plants/ha).

There is evidence that garlic grows best when there are about 600,000 plants/ha (Morav□evi□ et al., 2011). According to Karaye and Yakubu (2006), garlic plants become more luxuriant in thinner stands, while bulb yield increases at greater plant populations. The authors suggest that garlic should be grown in a thick stand to give priority to yield. Having studied plant populations between 330,000 and 1,300,000 plants per hectare, Kilgori et al. (2007a, b) found that garlic responded best to a stand of 600,000 plants/ha.

There is little information on the affects of plant density on garlic quality so the objective of this study was to determine the effects of different between-row spacing on growth, yield and quality of four local accession of garlic to reach maximum yield with the best quality.

Materials and Methods

The experiment was conducted at the National Rice Research Institute, Rasht, Iran, during 2008-2010. Table 1 refers to rainfall and temperature during experiment months in this region. It was laid out on factorial Randomized

Complete Block Design (4×2) with three replications during two years. Four local accession of garlic (Langroud, Tarom, Tabriz and Hamedan) were culture in three between-rows spacing (15, 25 and 35 cm). All conventional cultural practices were adopted as recommended for this region (Mahdieh Najafabadi et al., 2012). The soil in the field plots was a sandy loam, pH 7.4, EC of 0.08 ds cm^{-1}, and a C/N ratio of 0.43. Soil in the seedbeds was prepared by plowing and disking following local farm practices. The cloves were planted on November 5, 2008 and 2009, with a distance of 0.10 m between plants and harvested on 20 May 2009 and 2010 (Muro et al., 2000). The observations recorded during these studies were, bulb and neck diameter and their ratio (Forcing characteristics); bulb weight and yield were also recorded.

Table 1. Temperatures and rainfall at garlic planting site

Month	Nov.		Dec.		Jan.		Feb.		Mar.		Apr.		May.	
	2008	2009	2008	2009	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
Rainfall (mm)	178.9	170.0	238.4	94.7	149.0	47.9	66.2	127.5	27.3	89.8	133.0	74.4	44.9	140.0
Temperature (°C) Max.	17.4	18	14.1	15.0	9.6	14.3	12.8	10.2	15.9	13.7	16.8	16.2	22.2	21.0
Temperature (°C) Min.	10.5	10.7	5.9	5.9	2.2	7.3	4.9	3.5	5.8	7.7	6.0	8.3	12.8	14.0

Dry matter was determined by drying at 75±5°C until samples reached constant weight (AOAC, 1984). Total soluble solid contents (TSS) were determined by squeezing the tissue and placing one drop of juice from each sample into a refractometer (Atago HSR-500, Tokyo, Japan).

Methanol extracts of sample (1 g sample in 10 cc methanol) were used for determination of total phenolics. Total phenolic content was evaluated by colorimetric analyses using Folin-Ciocaltaue's phenol reagent (Singleton and Rossi, 1965; Hassan et al., 2013). The total phenolics content was expressed as mg galic acid equivalent/100 g of sample.

The free radical-scavenging activity against DPPH radical was evaluated with the methods of Leonge and Shui (2002) and Miliouskas et al. (2004) with minor modification. In the presence of an antioxidant, the purple color intensity of DPPH solution decays and the change of absorbance are followed spectrophotometrically at 517 nm.

Measurement of total flavonoids was performed according to method Bozin et al. (2008) and Baghiani et al. (2010). Potassium was measured by flame photometery (Model AT-8000, Gold, Shanghai, China) according to Feitosa et al., (2013); Mg and P were measured with a UV/Vis spectrophotometer (Model 6405, Jenway, Essex, UK).

Data were subjected to analysis of variance in SAS (SAS, Inc., Cary, NC). If interactions were significant they were used to explain the data. If interactions were not significant means were separated with Tukey test.

Results

There are significant differences between years so we analyzed each year data separately.

First year: Interaction between local accessions and between-row spacing had affected biomass, bulb yield, bulb antioxidant capacity, total phenol, flavonoids and P content significantly (Table 2-4).

Between row spacing had affected total yield, biomass, bulb yield, neck diameter, cormlet weight, corm ash, total phenol and flavonoids content significantly (Table 2-4). There are also significant differences between local accession on total yield, biomass, bulb yield, harvesting index, number of leaves, neck diameter, corm diameter, corm diameter to neck diameter ratio, corm height, corm weight, number of cormlet, cormlet weight, corm dry matter, TSS, antioxidant capacity, flavonoids and P content (Table 2-4).

The 15 cm between row lead to the highest total yield and corm ash and the lowest corm diameter and cormlet weight (Table 5).

Tarom accession had the higher harvesting index, number of leaves, corm diameter, neck diameter to corm diameter ratio, cormlet weight and corm dry matter and

Table 2. ANOVA table of affects of between row spacing and local accessions on garlic yield and yield component.

S.O.V.	d.f.	Total yield (t·ha^{-1})	Biomass (t·ha^{-1})	Plant weight (g)	Corm yield (t·ha^{-1})	Harvesting index (Corm yield/ Total yield)	Corm weight (g)	Number of cormlet	Cormlet weight (g)
First year									
Replication (R)	2	12.53ns	0.01ns	611.31ns	3.36ns	21.87ns	3208.98*	5.26ns	13.44**
Between row spacing (B)	2	570.58**	0.18*	4754.38ns	69.96*	18.14ns	399.57ns	4.81ns	8.18*
R*B	4	24.98	0.01	1961.06	8.07	40.56	266.35	3.92	0.49
Local accession (A)	3	94.6**	0.05**	912.64ns	26.17**	71.81**	260.68*	66.39**	56.5**
B*A	6	10.05ns	0.003*	587.96ns	1.72*	4.26ns	69.43ns	3.40ns	1.04ns
Error	18	3.85	0.001	527.01	0.44	4.53	80.12	7.78	2.06
C.V. (%)		8.08	7.45	12.59	7.61	5.93	12.96	15.98	10.19
Second year									
Replication (R)	2	0.48ns	0.002ns	27.12ns	0.41ns	11.39ns	43.01ns	7.80ns	0.01ns
Between row spacing (B)	2	101.38**	0.05**	27.43ns	21.79**	56.13*	64.21ns	0.08ns	1.33ns
R*B	4	3.06	0.001	38.41	0.82	8.05	17.89	2.74	0.21
Local accession (A)	3	4.78*	0.001ns	51.29*	0.87ns	28.75*	47.86*	8.22**	0.03ns
B*A	6	2.50ns	0.001ns	51.23*	0.38ns	29.93*	6.13ns	1.16ns	0.09ns
Error	18	1.28	0.001	13.49	0.31	8.83	9.54	0.96	0.19
C.V. (%)		15.83	17.53	9.24	15.49	5.83	12.75	9.94	17.20

Table 3. ANOVA table of affects of between row spacing and local accessions on garlic vegetative characteristics.

S.O.V.	d.f.	Plant height (%)	Number of leaves	Neck diameter (cm)	Corm diameter (cm)	Neck diameter/corm diameter	Corm height (cm)	Cormlet diameter (cm)
First year								
Replication (R)	2	271.57ns	111.47ns	16.73ns	51.72*	0.42ns	271.87ns	26.58ns
Between row spacing (B)	2	234.95ns	11.55ns	12.56ns	57.36*	0.41ns	117.33ns	1.47ns
R*B	4	62.34	32.64	7.24	5.62	0.48	46.04	4.55
Local accession (A)	3	70.32ns	320.75**	21.29*	88.32**	2.27**	110.32**	9.11ns
B*A	6	14.98ns	17.73ns	7.09ns	9.26ns	0.54ns	12.72ns	9.88ns
Error	18	24.58	23.37	4.42	9.16	0.38	7.92	44.46
C.V. (%)		5.76	31.13	12.10	4.99	17.19	6.36	10.86
Second year								
Replication (R)	2	87.61ns	30.71*	17.24ns	9.16ns	0.70*	11.58ns	4.83ns
Between row spacing (B)	2	53.65ns	3.33ns	1.50ns	7.31ns	0.05ns	2.30ns	7.25*
R*B	4	19.10	2.81	2.79	13.11	0.09	3.48	0.84
Local accession (A)	3	41.59ns	2.97ns	3.35ns	37.16**	0.14ns	4.37ns	2.48ns
B*A	6	13.95ns	7.29ns	1.98ns	13.38ns	0.14ns	2.88ns	1.48ns
Error	18	23.87	4.05	1.96	5.54	0.09	3.88	1.03
C.V. (%)		5.87	16.85	9.25	5.52	10.44	6.23	7.12

ns, **, *,: non significant and significant at P≤0.01 and P≤0.05 respectively

Table 3. Continue.

S.O.V.	d.f.	Cormlet width (cm)	Cormlet height (cm)	Corm height/ corm diameter
First year				
Replication (R)	2	11.2ns	15.52ns	0.03ns
Between row spacing (B)	2	6.11ns	0.25ns	0.01ns
R*B	4	6.86	2.86	0.01
Local accession (A)	3	15.53ns	4.40ns	0.03ns
B*A	6	10.83ns	6.33ns	0.02ns
Error	18	24.03	6.82	0.1
C.V. (%)		15.97	8.91	12.37
Second year				
Replication (R)	2	0.95ns	5.64ns	0.02ns
Between row spacing (B)	2	6.40*	14.39ns	0.01ns
R*B	4	0.74	2.11	0.01
Local accession (A)	3	0.38ns	3.39ns	0.01ns
B*A	6	0.65ns	0.55ns	0.01ns
Error	18	1.39	1.18	0.005
C.V. (%)		8.90	4.78	4.50

ns, **, *,: non significant and significant at $P \leq 0.01$ and $P \leq 0.05$ respectively

Table 4. ANOVA table of affects of between row spacing and local accessions on garlic qualitative characteristics.

S.O.V.	d.f.	Antioxidant (% DPPH reduction)	Total phenol (mg/100g FW)	Flavonoids (mg/100g FW)	Corm dry matter (%)	Leaf dry matter (%)	Corm ash (%)	TSS (°Brix)
First year								
Replication (R)	2	38.13*	953.17*	444.11**	31.97ns	26.71**	2.20**	7.36ns
Between row spacing (B)	2	1.56ns	3822.88**	1916.86**	0.02ns	2.11ns	1.65*	0.001ns
R*B	4	2.96	59.89	1.90	6.26	0.80	0.1	1.46
Local accession (A)	3	23.60**	27.66ns	587.44**	48.32**	0.33ns	0.92ns	10.87**
B*A	6	5.23*	454.04**	627.82**	1.42ns	0.53ns	0.75ns	0.34ns
Error	18	1.33	26.63	8.53	2.20	1.08	0.3	0.51
C.V. (%)		11.15	13.61	3.15	4.99	10.68	16.41	2.76
Second year								
Replication (R)	2	0.58ns	281.33*	576.33*	153.68*	1.42*	0.52ns	51.99ns
Between row spacing (B)	2	5.84ns	113.65ns	15.25ns	39.21ns	0.80ns	0.33ns	11.49ns
R*B	4	3.58	22.67	81.58	9.32	0.19	1.85	11.80
Local accession (A)	3	15.82*	1148.09**	1711.48ns	1.34ns	2.03ns	3.01ns	0.61ns
B*A	6	17.62**	1145.19**	628.07ns	4.73ns	0.28ns	0.85ns	3.27ns
Error	18	4.24	105.50	665.87	4.77	0.74	1.07	5.62
C.V. (%)		11.39	15.55	15.28	6.70	8.84	16.45	9.17

Table 4. Continue.

S.O.V.	d.f.	P (mg/100g FW)	K (mg/100 g FW)	Mg (mg/100g FW)
First year				
Replication (R)	2	1889.06ns	372.76ns	482.71*
Between row spacing (B)	2	2278.81ns	2124.58ns	5.35ns
R*B	4	387.64	4052.41	48.30
Local accession (A)	3	1200.14**	13404.44ns	99.70ns
B*A	6	899.35**	2573.12ns	45.47ns
Error	18	186.03	6646.63	97.12
C.V. (%)		10.89	21.81	14.09
Second year				
Replication (R)	2	45.32ns	15442.56ns	768.79*
Between row spacing (B)	2	610.34**	28890.73*	362.48*
R*B	4	16.25	2606.24	48.40
Local accession (A)	3	211.82*	649.45ns	39.68ns
B*A	6	222.01**	1944.68ns	42.49ns
Error	18	49.00	4203.18	61.47
C.V. (%)		5.87	16.18	10.04

ns, **, *,: non significant and significant at P≤0.01 and P≤0.05 respectively

Table 5. Effects of between row spacing on total yield, corm diameter, cormlet weight and corm ash in first year and total yield, biomass, corm yield, cormlet diameter, cormlet width, K and Mg in second year

First year				
Between row spacing	Total yield ($t \cdot ha^{-1}$)	Corm diameter (cm)	Cormlet weight (g)	Corm ash (%)
15	31.25a	58.09b	6.37b	3.75a
25	24.09ab	62.08a	6.94b	3.03b
35	17.47b	61.64a	7.99a	3.22b

Second year							
Between row spacing	Total yield ($t \cdot ha^{-1}$)	Biomass ($t \cdot ha^{-1}$)	Corm yield ($t \cdot ha^{-1}$)	Cormlet diameter (cm)	Cormlet width (cm)	K (mg/100 g FM)	Mg (mg/100 g FM)
15	10.21a	0.22a	4.95a	13.32b	12.46b	442.61a	83.7a
25	6.81ab	0.14b	3.54ab	14.71a	13.91a	359.12b	72.72b
35	4.43b	0.09b	2.26b	14.62ab	13.33ab	356.2b	77.81ab

Values in a column followed by the same letter are not significantly different

the lowest corm height and number of cormlet while the highest total yield and neck diameter was obtained from Hamedan and Langroud accessions respectively (Table 6).

The highest biomass, total yield, total phenol and flavonoids were obtained when corms cultured with 15 between rows. The highest antioxidant capacity of Hamedan and Langroud accession were obtained from 25 between row spacing while for Tarom and Tabriz the highest antioxidant capacity were obtained from 15 cm between row spacing. The highest p content for all accessions were obtained from 15 cm between row spacing except Tabriz accession that the highest P content was related to 25 cm between row spacing (Table 7).

Table 6. Effects of local accessions on total yield, harvesting index, number of leaves, neck diameter, corm diameter, neck diameter/corm diameter, corm height, corm weight, number of cormlet, cormlet weight, corm dry matter and TSS in first year and total yield, corm diameter, corm weight, number of cormlet in second year

First year								
Local accession	Total yield ($t \cdot ha^{-1}$)	Harvesting index (Corm yield/ total yield)	Number of leaves	Neck diameter (cm)	Corm diameter (cm)	Neck diameter/corm diameter	Corm height (cm)	Corm weight (g)
Hamedan	26.54a	36.94ab	19ab	17.79ab	62.88ab	3.74ab	46.31a	75.51a
Tarom	25.62a	39.26a	22.09a	15.12b	63.7a	4.24a	39.02b	71.55a
Langroud	25.46a	34.79bc	11.41bc	18.60a	58.19bc	3.17b	45.64a	64.79a
Tabriz	19.46b	32.69c	9.63c	17.96a	57.63c	3.22ab	46.05a	64.49a

First year				
Local accession	Number of cormlet	Cormlet weight (g)	Corm dry matter (%)	Corm TSS (°Brix)
Hamedan	12.00a	6.69b	30.19b	26.00b
Tarom	6.67b	10.76a	32.83a	27.24a
Langroud	11.93a	5.57b	27.69b	24.81b
Tabriz	12.33a	5.39b	28.27b	25.08b

Second year				
Local accession	Total yield ($t \cdot ha^{-1}$)	Corm diameter (cm)	Corm weight (g)	Number of cormlet (cm)
Hamedan	7.70a	42.07ab	25.05ab	9.36ab
Tarom	7.85a	40.04b	21.27b	8.67b
Langroud	6.43a	44.75a	26.76a	10.92a
Tabriz	6.62a	43.58ab	23.86ab	10.22ab

Values in a column followed by the same letter are not significantly different

Second year: Interaction between local accessions and between-row spacing had affected plant weight, harvesting index, bulb antioxidant capacity, total phenol, and P content significantly (Table 2-4). Between row spacing had affected total yield, biomass, and bulb yield, harvesting index, cormlet diameter, cormlet width, P, K and Mg content of bulb significantly (Table 5). There are also significant differences between local accession on total yield, plant weight, harvesting index, corm weight, number of cormlet, antioxidant capacity, flavonoids and P content (Table 6). 15 cm between row lead to the highest total yield, biomass, bulb yield, K and Mg and the lowest cormlet diameter and width (Table 5). Langroud accession was the best accession in second year according to all significant characteristics (Table 6). The highest plant weight of Tarom and Langroud accession were obtained from 35 cm between row spacing while for Hamedan and Tabriz the highest plant weight was obtained from 15 and 25 cm between rows spacing respectively (Table 7).

The highest harvesting index for all accessions were obtained from 25 cm between row spacing except Tabriz accession that the highest harvesting index was related to 35 cm between row spacing (Table 7). The highest antioxidant capacity of Hamedan, Tabriz and Tarom accession were obtained from 15 cm between row spacing while for Langroud accession the highest antioxidant capacity were obtained from 25 cm between row spacing (Table 7). The highest total phenol of Tabriz and Langroud accessions were obtained from 35 cm between row spacing while for Hamedan and Tarom accessions the highest phenol content were obtained from 25 and 15 cm between rows spacing respectively (Table 7). The highest p content for all accessions was obtained from 35 cm between row spacing (Table 7).

Table 7. Effects of local accessions and between row spacing interaction on biomass, bulb yield, antioxidant capacity, total phenol, flavonoids and P in first year and plant weight, harvesting index, antioxidant, total phenol and P in second year.

First year

Local accession	Between row spacing	Biomass ($t \cdot ha^{-1}$)	Corm yield ($t \cdot ha^{-1}$)	Antioxidant capacity (% DPPH reduction)	Total phenol (mg/100g FM)	Flavonoids (mg/100g FM)	P (mg/100g FM)
Hamedan	15	0.6±0.06	12.18±1.42	3.31±1.89	66.51±5.79	108.67±8.50	146.6±13.54
Hamedan	25	0.46±0.04	10.62±1.55	5.71±1.82	20.91±8.01	107.33±7.51	92.22±10.87
Hamedan	35	0.31±0.02	6.54±0.58	4.72±2.18	31.84±7.63	83.67±10.69	128.67±13.08
Tarom	15	0.61±0.1	12.36±1.82	4.39±2.08	55.57±8.01	92.33±5.51	167.47±11.2
Tarom	25	0.45±0.03	9.77±1.1	3.41±1.89	24.64±8.43	74.33±5.51	127.55±14.22
Tarom	35	0.38±0.02	8.07±0.75	3.38±1.84	29.71±16.03	78±3	131.91±14.32
Langroud	15	0.53±0.05	11.8±1.16	8.14±1.82	59.31±8.21	80.33±5.13	132.26±14.86
Langroud	25	0.43±0.05	9.17±1.62	8.19±2.09	48.37±8.05	118.33±3.51	98.65±37.48
Langroud	35	0.27±0.01	5.76±0.52	5.73±4.02	9.44±7.2	77.33±4.51	126.07±24.11
Tabriz	15	0.4±0.13	7.77±2.62	7.38±1.53	52.11±7.69	114.67±3.51	110.65±9.16
Tabriz	25	0.32±0.06	6.67±1.46	4.62±2.25	25.17±16.09	103.33±10.5	128.33±26.27
Tabriz	35	0.21±0.05	4.52±0.65	6.5±1.4	31.31±16.21	73.33±5.51	113.1±18.76

second year

Local accession	Between row spacing	Plant weight (g)	Harvesting index (corm yield/total yield)	Antioxidant capacity (% DPPH reduction)	Total phenol (mg/100g FM)	P (mg/100g FM)
Hamedan	15	40.81±5.29	48.2±1.52	7.95±0.28	9.44±3..2	113.55±1.84
Hamedan	25	43.63±2.9	47.83±1.83	4.58±1.63	43.57±10.44	116.95±5.36
Hamedan	35	38.67±5.53	49.32±4.25	4.05±1.15	34.24±13.88	112.43±2.29
Tarom	15	35.27±2.34	48.71±2.2	7.3±3.64	54.24±10.4	102.33±7.27
Tarom	25	38.78±0.96	52.88±4.07	3.39±1.09	43.31±5.21	121.86±4.05
Tarom	35	41.72±0.45	53.44±2.78	9.07±0.21	17.97±3.61	120.93±3.65
Langroud	15	44.98±6.82	50.9±1.5	3.09±1.79	35.84±18.81	109.68±7.67
Langroud	25	39.90±1.01	50.9±1.43	2.74±1.02	35.84±2.4	132.62±10.87
Langroud	35	36.75±7.45	51.09±4.34	7.68±2.65	5.44±2.88	125.2±9.13
Tabriz	15	44.64±3.17	51.74±1.44	4.36±1	54.77±2.81	121.04±8.43
Tabriz	25	31.44±4.03	59.72±2.58	3.01±2.4	63.31±17.2	116±2.94
Tabriz	35	40.5±4.74	47.27±4.71	6.15±3.06	33.71±12.01	138.3±7.67

Values in a column followed by the same letter are not significantly different

Discussion

As mention above, the results of two cultivated years were different. Garlic is a sensitive plant to water and high temperature stress (Miko et al., 2000). In first year the higher rainfall (658.8 mm) in comparison to second year (574.3 mm) and lower mean temperature (10.7 °C) compaired to second year (11.4 °C) lead to better results.

Plant density changed when garlic cultured with different between row spacing. Previous studies carried out on plant density indicate its direct influence on yield (Castille et al., 1996; Castellanos et al., 2004). In present research plant yield increased when the lower between row spacing and high plant density were used but the yield improvement occurring at increased plant stand is offset by the reduction in bulb size and some quality indices such as total phenol and antioxidant which severely affects quality and market value, when garlic is produced for fresh market (Castellanos et al., 2004). However different local accessions differently response to between row spacing.

The number of leaves the most important part of the plant for photosynthetic activity per plant doesn't changed in each accession but their size increased by increasing between row spacing. In addition, photosynthesis depends on the genotype (Moracevic, 2011). Genotypes which had the higher leaves produce bigger corm. In other hand by increasing between row spacing and leaves surface bigger corm were harvested. Similar to previous research our results indicated that there is no single, universal plant density that would be optimal for a garlic crop regardless of the soil and climatic conditions it is grown under.

Conclusions

Moderate between row spacing and plant density for fresh market garlic and low between row spacing and high plant density for higher yield is proposed according our results. More work is needed to select best culturing system for each variety and environment and select characteristics that are stable in different environment.

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