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Developmental Changes in Growth, Yield and Volatile Oil of Some Chinese Garlic Lines in Comparison with the Local Cultivar "Balady"

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Abstract: Balady cultivar and six Chinese lines were planted to study their developmental growth, yield and essential oil variations. Bulb of Balady cultivar had more two folds of cloves number per bulb than the Chinese lines. On the contrary Balady cv had the lowest clove weight compared to all Chinese lines. Chinese lines significantly surppassed the Balady cultivar in the bulb yield ha^{-1}. The bulb yield ha^{-1} could be arrangement in descending order as follow Line B>Line F>Line D>Line C>Line A>Line E>Balady cv. Line B significantly surpassed the other tested lines in oil yield and had 7 folds oil yield plant^{-1} than the local cultivar. The main compound in the bulb was found to be methylallay disulfide in both Chinese lines and Balady cultivar. Some components which found in the garlic bulbs at the age 150 days disappeared at the maturity time. Chinese Line B recorded the highest bulb yield and volatile oil content comparing with other lines.

Key words: Egypt, *Allium sativum*, leaf area, vegetative stage, bulb diameter, harvest index

INTRODUCTION

Garlic (*Allium sativum* L.) is one of the most important vegetable crops in Egypt, as to exportation or for local consumption. Garlic has been used for many medicinal purposes (Ledezma and Apitz-Castro, 2006). Garlic oil (0.5%) had herbicidal (Abouziena *et al*., 2009), acaricidal (Ismail *et al*., 2011) and insecticidal (Alexenizer and Dorn, 2007; Dauda *et al*., 2012; Sharaby *et al*., 2012) properties, with a broad-spectrum of activity. The extracts of garlic plant reduced linear growth of soilborne fungs that causing damping-off and powdery mildew diseases (Morsy *et al*., 2009). Also, garlic volatiles oil used as bud induction agents in organic farming of table grape (Vargas-Arispuro *et al*., 2008).

Studies regarding the seasonal developmental growth of the garlic plant are of value in planning of improving the management practices in irrigation, fertilization, pest control etc., Garlic cultivars either Egyptian or foreign (as Chinese lines) are varied in their growth, essential oils and yield potentiality (Walters, 2008; Al-Otayk *et al*., 2008; Abdel-Razzak and El-Sharkawy, 2013). Garlic cultivars when grown under the same environmental conditions were vary traits include the leaf number before bolting, flowering date, final stem length, flower/topset ratio and pollen viability (Kamenetsky, 2007; Volk and Stern, 2009). Also, the chemical constituents of garlic leaves and bulbs were varied according to types (El-Zemaity *et al*., 2009).

Thus, the present work aimed to study the developmental changes in growth, volatile oil and yield potentiality of some Chinese lines in comparison to the local cultivars "Balady".

MATERIALS AND METHODS

A locally propagated cultivar of garlic (*Allium sativum* L) "Balady" and six lines of Chinese garlic (A, B, C, D, E and F) were planted in 20th October in the two winter successive seasons of 2009/2010 and 2010/2011 in a sandy loam soil at private farm, Kaluobia Governorate, Egypt. Garlic cloves were planted on both sides of rows spaced 60 cm apart with 7.0 cm spacing between hills. All agricultural practices for growing garlic were done as the recommendations of the Ministry of the Agriculture in Egypt. Garlic seeds (cloves) of the Egyptian cultivar and the six Chinese lines (Lines A, B, C, D, E and F) were obtained from Horticulture Research Institute, Agriculture Ministry, Egypt.

Data recorded

Vegetative growth: Samples, 5 plants, were randomly taken from each plot at 120 and 150 Days after Planting (DAP) and the following criteria were recorded: Plant height, leaves number, leaves area/plant, fresh and dry weight of leaves, bulb diameter, bulb weight, cloves number/bulb, clove weight and bulb. The area of the leaf (lamina) was determined according to the leaf parameter method by Dzamic *et al*. (2001) and expressed as cm^2/plant. The method calculates the area as a product of leaf length, leaf width and a correction factor, which we determined ourselves (0.72) (Moravcevic *et al*., 2011).

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Yield and its components: At harvesting time (185 days after planting), all plants of each plot were harvested and the total yield per hectare was calculated after curing for 7 days. In addition, 5 bulbs were randomly collected from each plot to determine bulb weight, bulb diameter and number of cloves per bulb.

Chemical constituents: Volatile oil of leaves at age of 120 and 150 DAP and in the bulb at age of 150 and 185 DAP were extracted by water distillation of leaves or the outer cloves according to Guenther (1965).

The obtained Garlic volatile oil was dehydrated over unhydrus sodium-sulphate and then subjected for GLC analysis with varian, VistA ser 6000, FID model. The separation was carried out by 2 m×1/8 in O.d. Stainless steel 3% ov-101 column. The carrier gas (nitrogen) to flow rate of 50 mL min^{-1} was maintained, while the column temperature was programmed from 80 to 200°C at a rate of 4°C min^{-1}. The injection port temperature was maintained at 180°C and detector at 240°C. The relative was determined by varian 4270 integrator.

Statistical analysis: A combined analysis of data of growth and yield parameters for the two seasons was carried out according to the procedure outlined by Gomez and Gomez (1984). For comparison between means, the LSD test at 5% level was used.

RESULTS AND DISCUSSION

Vegetative growth: Data in Table 1 show that plant height, leaves area/plant and fresh and dry weights per plant were significantly differed among garlic varieties (Table 1). Plants of Line A and Line C were the tallest; whereas Balady plants cv were the shortest one. Insignificant difference were noticed among the Egyptian variety and Chinese Line F in the plant height at 120 days after Planting (DAP) but the other Chinese lines were significant more taller than Egyptian cultivar. While at 150 DAP the Egyptian cultivar appeared to be tallest than that of Chinese lines (D and F) but shorted than that of lines (A, B, C and E). These results are in agreement with the finding of Al-Otayk *et al.* (2008) and Abdel-Razzak and El-Sharkawy, 2013. They found that Balady cv. recorded the longest plants; however, Chinese plants detected the heaviest leaves dry weight. They added that these results might be expected based on the genetic structure that characterized each garlic cv. and the differences between genotypes.

Insignificant differences were recorded among the cultivars tested in the leaves number/plant at 120 and 150 DAP, however Chinese lines had more leaves number compared to Balady cultivar (Table 1).

Concerning the leaf area, which determines how much sunlight will be absorbed by the plant, the results in Table 1 revealed that Chinese Line A surpassed the other tested Egyptian cultivar and Chinese lines in the leaves area per plant recorded at 120 and 150 DAP. The Egyptian cultivar came in the second order in this respect at 120 DAP, while at 150 DAP all Chinese lines recorded more significant leaves area per plant than that of Egyptian variety.

Concerning the fresh and dry weight of leaves, bulb and whole plant at 120 and 150 DAP, the data in Table 1 and Fig. 1 indicated that Chinese line A recorded the highest fresh and dry weight of leaves at 120 DAP, while the maximum bulb fresh and dry weights were recorded with line C, consequently the greatest fresh and dry

Table 1: Developmental growth of Egyptian cultivar and six Chinese lines of garlic at 120 and 150 days after planting (average of two successive seasons)

				Leaves weight (g $plant^{-1}$)		Bulb weight (g $plant^{-1}$)	
Cultivars	Plant height (cm)	Leaves No/plant	Leaves area (cm^2/plant)	Fresh	Dry	Fresh	Dry
1st sample (120 days after planting)							
Balady	51.4	7.4	310.0	18.8	3.6	8.7	2.8
Line A	63.1	8.1	348.8	47.9	6.8	13.6	4.1
Line B	57.4	8.8	237.0	31.8	4.2	15.6	4.2
Line C	60.8	8.4	190.0	34.6	5.4	17.5	5.9
Line D	55.4	8.3	251.0	28.7	6.1	15.4	4.6
Line E	56.1	8.4	193.1	21.7	4.8	10.9	3.4
Line F	52.8	7.8	204.6	23.8	5.5	11.9	3.7
LSD at 5%	2.3	N.S	21.4	7.5	0.3	2.1	0.5
2nd sample (150 days after planting)							
Balady	60.1	7.6	310.0	37.6	6.2	25.0	15.6
Line A	69.4	8.8	522.3	51.8	15.8	26.6	14.7
Line B	63.1	8.7	370.4	46.8	9.4	15.0	10.0
Line C	67.6	8.3	382.4	50.6	17.7	32.0	17.9
Line D	56.4	9.3	377.6	36.6	9.3	28.7	19.7
Line E	65.4	9.0	352.1	27.2	6.6	13.7	8.7
Line F	53.8	8.1	360.1	31.5	6.1	17.0	10.9
LSD at 5%	2.8	N.S	19.4	6.3	2.4	3.4	2.5

weight of plant was recorded with the Chinese line A followed by Line C, while Balady *cv* gave the lowest fresh and dry weight of plant at 120 DAP. At 150 DAP Line C surpassed all the garlic cultivars in the plant fresh and dry weight and gave more fresh and dry weights of plant by 32.0 and 63.3%, respectively if compared to Balady cultivar. Line E recorded the lowest fresh and dry weight of leaves, bulb and plant compared to the other Egyptian variety and Chinese lines (Table 1). Al-Otayk *et al*. (2008) reported that Chinese Line (L4) had the maximum plant dry weight and the highest chlorophyll content, while bulb fresh and dry weight of Egyptian cultivar (Balady) was the lowest among the cultivars and lines tested.

Yield and its attributed: Table 2 and Fig. 2 illustrated that there was a significant difference among the tested garlic cultivars in yield parameters. The Egyptian cultivar" Balady" had the highest leaves fresh weight at maturity stage, while Chinese Line E had the lowest one. Insignificant differences were recorded among the garlic varieties in the bulb diameter criteria, however all chinease lines had a bulb with larger diameter than Balady cv and Chinese Line B had the highest bulb diameter than the other tested varieties (Table 2). On the other hand, bulb of Balady cultivar significant surpassed the Chinese lines in cloves number/bulb, where Balady cv had more two folds of cloves number per bulb than the Chinese lines. On the contrary of cloves number/bulb

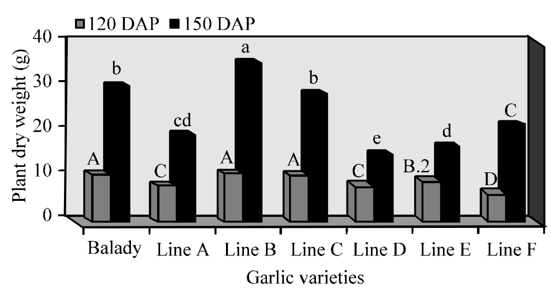

Fig. 1: Plant dry weight of Egyptian garlic cultivar and six Chinese lines plants at 120 and 150 days after planting (DAP)

character, Balady cv had the lowest clove weight compared to the all Chinese lines. Line B had the greatest clove weight (2.55 g) which exceeded five times than that of Egyptian cultivar (0.49 g). The greater clove weight was considered advantage to the domestic consumer usage, where its easy to remove the outer layer before using it in foods. Therefore the Egyptian consumers prefer the chinease lines for this reason. Mahmood ***et al.*** (2002) reported that lowest number of cloves/bulb in cv. Chinese showed the big size cloves which is an advantage for peeling but at the same time requires more seed rate/hectare. Concerning the bulb weight, Data in Table 2 indicated that Balady cv had the lowest bulb weight compared to all Chinese lines. This result may be attributed to the smallest weight of clove, however the bulb of Egyptian cultivar had more cloves number, than that of Chinese lines. Similar finding was reported by Omer and Abou-Hadid (1992) and Al-Otayk *et al*. (2008).

Among cultivars tested the Chinese lines had the highest harvest index (HI), where the HI for the Chinese lines ranged between 42.6-64.4, while the HI for the Balady cv. was 37.6. These results could be explained due to the high coefficient migration in the Chinese lines and to its high potentiality carbohydrates synthesis (Midan *et al*., 1992).

Table 2 indicated that among the garlic cultivar and lines, line B had the largest biological yield followed by lines F, C, D and A, while insignificant difference was recorded between Egyptian cultivar and Chinease Line E, where they recorded the lowest biological yield. Therefore, these Chinese lines can be utilized as new cultivars in Egyptian cultivation.

Concerning the bulb yield per hectare, Fig. 2 indicated that Chinese Line B gave the highest bulb yield and significantly surppassed the Balady cultivar by 155.1%. Insignificant difference in bulb yield ha^{-1} was recorded among the Chinese lines B, F and D (Fig. 2). The bulb yield ha^{-1} could be arrangement in descending order as follow: Line B (15.900)>Line F (14.133)>Line D (14.000) Line C (12.233)>Line A (11.733)>Line E (6.767)>Balady cv. (6.233).

These results are in agreement with those obtained by Mahmood ***et al.*** (2001, 2002) who reported that the

Table 2: Bulb yield criteria of Egyptian garlic cultivar and six Chinese lines at harvest (average of two successive seasons)

Cultivars	Leaves fresh weight (g $plant^{-1}$)	Bulb diameter (cm)	Cloves No./plant	Clove weight (g)	Bulb weight (g)	Biological yield (g $plant^{-1}$)	Harvest index (%)
Balady	31.1	2.4	37.0	0.49	18.7	49.8	37.6
Line A	27.0	3.0	16.1	2.03	35.2	62.2	56.6
Line B	28.0	3.4	17.1	2.55	47.7	75.7	63.0
Line C	29.8	2.9	16.3	2.10	36.7	66.5	55.2
Line D	23.4	3.3	15.9	2.43	42.0	65.0	64.4
Line E	27.4	2.5	14.0	1.24	20.3	47.7	42.6
Line F	28.7	3.0	15.7	2.39	42.4	71.1	59.6
LSD at 5%	3.4	N.S	3.8	0.61	4.5	5.7	3.1

average bulb weight in cv. Chinese was significantly higher than rest of cultivars. The cultivar "Chinese" was found to be high yielding with 11.6 tones bulb yield per hectare. The greatest bulb yield ha^{-1} of Chinese lines than Balady cultivar attributed to that superior lines had a largest clove and bulb weights (Table 2). On the contrary, Abdlkader-Helmy *et al.* (2011) and Abdel-Razzak and El-Sharkawy (2013) showed that Balady cv. gave the heaviest total bulb yield (5.048 and 4.548 ton ha^{-1}) and the biggest number of cloves/bulb (28.45 and 23.22) compared with Chinese one (4.143 and 3.643 ton ha^{-1}) and (19.70 and 19.97 cloves number).

Volatile oil: The volatile oil percentage in both leaves and bulbs of Balady cultivar and six Chinese lines are shown in Table 3. At 120 DAP, the volatile oil of leaves ranged from 0.001% (Balady cultivar) to 0.007% (Chinese Line B) on the basis of fresh weight. No considerable increase was observed with the volatile oil progress of the age of leaves, while volatile oil of bulbs increased towards maturity. It's clear that the volatile oil content of Chinese Line B bulbs was higher than the other lines.

The data in Table 3 indicated that all Chinese lines had more volatile oil yield $plant^{-1}$ than the Egyptian cultivar. The increment of oil yield in Chinese lines than the local variety ranged from 42.1% (Line D) to 205.3%

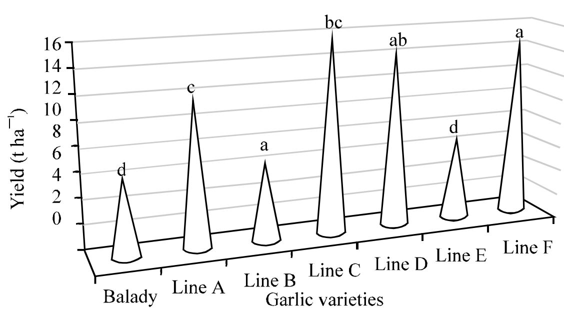

Fig. 2: Bulb yield (t ha^{-1}) of Egyptian garlic cultivar and six Chinese lines plants

with Line B. Line B significantly surpassed the other tested varieties in oil yield (0.028 mL $plant^{-1}$) and had 7 folds oil yield $plant^{-1}$ than the local cultivar (0.004 mL $plant^{-1}$) as shown in Table 3. Edris and Fadel (2002) reported that the yield of garlic leaf oil obtained by distillation is 0.06% (based on fresh leaf weight) which is about 60% of the yield of Egyptian garlic pulp oil (0.1%) and about 30% of the yield of Chinese garlic bulb oil (0.2%). They added that fortification of garlic pulp oil with green garlic leaf oil means an increase of bulb oil quantity of 30-60% as well as an enrichment of the bulb oil with potent flavoring and pharmaceutical components.

Gas liquid chromatography analysis: Essential oils are complex mixers comprising many single compounds. Chemically they rederived from terpenes and their oxygenated compounds (El-Meleigy *et al.*, 2010). The main compound of the volatile oil of Balady cultivar and six Chinese lines that separated by GLC as well as their relative percentages are shown in Table 4. Nine compounds have been identified out of the 12 major compounds detected the volatile oil of garlic cultivars under investigation. The essential oils were analyzed by gas chromatography-mass spectrometry (GC-MS).

Data tabulated in Table 4 indicated that the relative percentages of the main compounds of the volatile oil in leaves at the age of 120 days. It can be noticed that the identified compounds represented 62.22 to 93.08% of total compounds. The major compound was found to be methyl allay disulfide for Balady cultivar, Chinese Line A, B, C, D and Chiperply disulfide for Chinese Line F. Methyl allay disulfide and Chiperpl disulfide ranged from 16.6- 61.4% and 2.8-24.7%, respectively. Li *et al.* (2010) found that major essential oil components were 3-vinyl-4H-1,2-dithiin (31.89%), diallyl trisulfide (13.31%), diallyl sulfide (2.22%), dially disulfide (6.87%), propyl allyl disulfide (13.89%) and dimethyl disulfide (7.05%). While, Edris and Fadel (2002) reported that the most prominent compounds of the essential oil in the leaves of Egyptian garlic were diallyl trisulfide (32.32%), followed by diallyl

Table 3: Volatile oil (%) of Egyptian garlic cultivar and six Chinese lines at different ages (average of two successive seasons)

	At 120 days after planting		At 150 days after planting		At harvest stage (185 days after planting)				
						Bulb			
Cultivars	Leaves	Bulb	Leaves	Bulb	Leaves	Oil %	% Increase	Oil yield (mL $plant^{-1}$)	% Increase
Balady	0.001	-	0.001	0.003	-	0.019	-	0.004	-
Line A	0.002	-	0.002	0.008	-	0.036	89.5	0.013	225
Line B	0.007	-	0.008	0.028	-	0.058	205.3	0.028	600
Line C	0.003	-	0.002	0.013	-	0.045	136.3	0.016	300
Line D	0.003	-	0.003	0.010	-	0.027	42.1	0.011	175
Line E	0.004	-	0.002	0.002	-	0.038	100.0	0.008	100
Line F	0.003	-	0.001	0.013	-	0.042	121.1	0.018	350
LSD at 5%	0.002	-	0.002	0.002	-	0.011	-	0.005	25

Table 4: Relative percentages of the main compounds of the volatile oil (by GLC) in the leaves of Egyptian garlic cultivar and six Chinese lines at 120 days after planting and in bulbs at 150 days after planting and at harvest stage

		Chinese lines					
Compounds	Balady	A	B	C	D	E	F
Garlic leaves at 120 days after planting							
Propyl thiol	0.04	0.17	0.09	-	0.13	0.17	0.22
Allyl sulfide	0.04	0.31	0.02	-	0.13	0.114	0.31
Chiperply disulfide	23.65	2.80	24.27	17.04	22.37	20.41	18.50
Allyl methyl sulfide	6.41	3.73	7.73	6.80	9.51	10.21	5.61
Dimethyl disulfide	3.84	0.18	3.17	3.60	3.59	0.21	7.26
Allyl mercaptam	2.51	0.90	0.24	0.03	-	0.19	0.89
Methyl allyl disulfide	38.23	61.66	44.10	56.40	47.47	42.53	16.57
Diethyl disulfide	0.45	0.80	-	-	0.46	0.23	8.15
Dimethyl trisulfide	5.59	9.36	11.23	8.88	8.70	6.14	4.70
Unidentified	19.24	19.76	9.15	6.92	7.64	9.736	37.79
Garlic bulb at 150 days after planting							
Propyl thiol	0.50	1.83	0.55	0.90	1.96	2.03	5.12
Allyl sulfide	18.50	14.85	39.40	38.72	42.30	24.56	38.12
Chiperply disulfide	40.40	21.01	31.90	31.28	32.81	35.29	19.78
Allyl methyl sulfide	1.00	0.99	3.32	1.73	0.35	0.22	4.60
Dimethyl disulfide	0.82	0.74	0.70	0.54	0.28	0.29	0.13
Allyl mercaptam	9.52	7.75	9.16	7.41	4.95	7.19	4.02
Methyl allyl disulfide	6.20	4.89	8.40	0.23	0.30	1.83	0.46
Diethyl disulfide	3.50	7.75	0.30	0.47	0.49	0.54	0.59
Dimethyl trisulfide	0.90	1.36	0.31	0.64	0.45	0.22	0.16
Unidentified	8.68	38.83	5.96	8.08	16.11	28.23	26.90
Garlic bulb at harvest stage (185 days after planting)							
Propyl thiol	20.30	0.06	1.81	2.38	-	038	0.16
Allyl sulfide	-	0.03	0.03	1.02	0.05	-	0.21
Chiperply disulfide	3.72	25.95	18.61	21.03	22.11	1.22	28.71
Allyl methyl sulfide	-	9.87	17.82	11.80	3.70	-	8.71
Dimethyl disulfide	-	0.27	0.23	0.14	0.95	0.70	0.16
Allyl mercaptam	-	0.77	0.84	1.29	-	-	0.74
Methyl allyl disulfide	58.09	46.47	38.99	41.49	54.38	77.89	51.77
Diethyl disulfide	1.31	-	0.20	2.27	0.24	0.58	1.14
Dimethyl trisulphide	9.13	11.05	8.56	11.49	11.89	14.86	5.71
Unidentified	7.45	6.00	6.97	7.39	6.61	4.37	2.99

disulfide (31.35%) and methyl allyl trisulfide (11.40%); these compounds are the same as those found in garlic bulb oil. They added that there is no data available in the literature about garlic leaf oil with which to compare our data, we found that our data agree with that reported on garlic bulb essential oil (Yu *et al*., 1989) concerning the abundance of these three allyl compounds as major components. These compounds are essential for giving the characteristic pungent garlic flavor. They also reported that there are other sulfur-containing compounds also present in garlic bulb oil e.g. methyl allyl trisulfide (1.81%), propyl allyl trisulfide (2.33%) and isobutyl isothiocyanate (2.28%). There are also some small amounts of components present in garlic leaf oil which are considered to be potent garlic flavoring compounds e.g., dimethyl trisulfide (0.41%) and diallyl sulfide (0.40%).

The relative percentages of the main compounds in the volatile oil of garlic bulbs at harvest are presented in Table 4. The identified compounds represented 92.55% to 97.21% of total compounds. It's clear that the main compound was found to be methyl allay disulfide in both Chinese lines and Balady cultivar, which ranged from 39 to 77 and 2.8%. While the main compound followed by propyl thiol (20.3%) in local cultivar, Chinese lines showed chioperpyl disulfide (18.06- 28.2%) as the second main compound, except for Line E which showed dimethyl trisulfide (14.9%) as the second main compound. Also local cultivar (Balady) showed propyl thiol with 20.3%, while the same compound showed an inconsiderable amount in Chinese lines. On the other hand, allyl methyl sulphide not detected neither in Balady cultivar nor in Chinese Line E, while this compound accounted 17.8% in the Line B (Table 4). Jirovetz *et al*. (1992) reported that as sulphur-containing main constituents (concentration higher than 1%) of this oil, diallyltrisulphide (29.7%), diallyltetrasulphide (4.4%), diatlyldisulphide (3.2%), diallylsulphide (2.5%) and methylallyltrisulphide (2.1%) were identified in Egyptian garlic bulb. While, (El-Meleigy *et al*., 2010) reported that the major components in garlic oil were dilly trisulfide (34.29%) anddiallyldislfide (allicin) (28.39%). El-Zemaity *et al.* (2009) reported that nine sulfur compounds were separated and identified; the major compound was Diallyl trisulfide (i.e., 49.82 and 46.17%) for Egyptian and Chinese lines, respectively. They added that Allyl methyl trisulfide ranged from 11.40 to 23.15% between cultivars.

From Table 4 it can be mentioned that some components which found in the garlic bulbs at the age 150 days disappeared at the maturity time. For instance, propyl thiol in Line D, allyl sulfide an allyl methyl sulfide in Balady cultivar and Chinese Line E, dimethyl sulfide in Balady cultivar and diallyl disulfide in Line A. These changes in the compounds during plant life may be attributed to their metabolism to other compounds. These results are in agreement with those reported by Khalaf and Taha (1988) who found that propyl thiol and methyl disulfide represented 50 and 21.6% in the volatile oil of Chinese garlic, respectively. Typical volatiles in crushed garlic and garlic essential oil include diallyl sulfide, diallyl disulfide, diallyl trisulfide, methyl allyl disulfide, methyl allyl trisulfide, 2-vinyl-1, 3-dithiin, 3-vinyl-1,2-dithiin (Fenwick and Hanley, 1985; Li *et al*., 2010). Montano *et al*. (2011) reported that there was a significant effect of the location, cultivar and garlic ecotype on individual organosulfur compound contents of garlic. They added that Discriminant analysis evidenced the ability of organosulfur compounds to distinguish among garlic bulbs from different locations or ecotypes with 81 or 86% accuracy, respectively.

CONCLUSION

Line B significantly surpassed the other tested varieties in oil yield and had 7 folds oil yield plant^{-1} than the local cultivar. It could be concluded that the Chinese lines can be utilized as new cultivars in Egyptian cultivation.

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