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Short Communication

Bulb Production of 38 Iranian Garlic (*Allium sativum* L.) Cultivars in Greenhouse Conditions

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Abstract

The study was carried out with 38 collected garlic (*Allium sativum* L.) cultivars from 3 important garlic production area in Iran (Zanjan, Hamadan and Mazandaran). The cloves were planted in 30 × 30 cm pots in control conditions (average temperature: 20 °C and 60 % RH). Randomized complete block design with 3 replications was conducted. The bulbing characteristics such as bulb weight, bulb circumference and number of cloves per bulb were evaluated. Although all 38 parental bulbs had multiple cloves, but only few cultivars have produced multi cloves in greenhouse conditions. Two classes of garlic cultivars were observed. Class A including 26 cultivars formed only single clove that their bulb weights were varied between 7 to 25.2 g. Class B including 12 cultivars were produce normal bulbs. The cultivar of Zanjan had the biggest bulbs (65 g in average) and others (Tarom 9, Tarom 14 & Hamadan1-5) were intermediate (with the average weight of 40 g). The number of clove in each bulb in class B was 6-11. Identification and assessment records revealed that 83 % of cultivars in class B are multi cloves related to owned areas that planted in the spring seasons such as Zanjan and Hamadan (cold regions). Our research demonstrated that normal bulbing in garlic can be done successfully in greenhouse depend on genotype. We identified 12 Iranian garlic genotypes for greenhouse planting which can produce normal and commercially multi cloves successfully. Other 26 genotypes that produced single clove were suitable for cooking usages due to easy skin peeling. Selection and introduce of suitable genotypes for greenhouse planting with normal bulbing, increase the garlic production in cold provinces and can serve in genetic and physiological studies as well as in breeding programs.

Keywords: Garlic, *Allium sativum* L., Bulbing, Single clove.

Introduction

Garlic (*Allium sativum* L.) is among the earliest domesticated plants and ranks the second after onion among onion crops in order of importance and cultivation [1-3]. Evidence of garlic cultivation can be found as far back as 3200 B.C. in Egypt. It continues to be an important part of Mediterranean, European and Asian diets as a food item, as well as a medicinal plant used to treat a variety of ailments [4]. Garlic has been well-known for its health benefits for centuries. Numerous properties have been reported as antifungal, antibacterial, antiviral, antithrombotic, antitumor, hypotensive, hypoglycemic and hypolipidemic [5,6]. More recently it has also been described with therapeutic values related to cardiovascular diseases, cholesterol metabolism and atherosclerosis [7] but also cancer [8]. These benefits are probably linked to the high amount of organosulfur compounds, and particularly of thiosulfinates, found in the garlic bulbs [9,10].

Garlic is a diploid species (2n=2x=16) of obligated apomixes, therefore its reproduction is vegetative [11]. Its vegetative mode of reproduction was probably promoted along centuries, via cloves or top-sets (aerial bulblets), which gave rise to vigorous plants and large bulbs. The growth stages

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of *A. sativum* include clove sprouting, shoot growth, bulb growth and maturation [12]. Clove sprouting and emergence are controlled mainly by temperature [4]. The early growth stage of garlic is suited by exposure of cloves to low temperature. Such exposure could be achieved by using controlled temperature chambers such as refrigerators [12] or planting in a cool growing period and this treatment is essential for proper development of shoot and good yield of bulb [13]. Recommendations suggest that garlic intended for consumption be stored at -1 to 0 °C. Base on some scientific reports, bulbing of garlic is controlled by the day length and temperature to which the dormant cloves and growing plants are exposed before bulbing begins [14]. Delay of a few weeks in the normal planting date lead to several losses in yield [15,16]. Plant growth regulator like gibberellic acid (GA3) has been known to play a vital role in bulbing of garlic. It has also been reported that foliar spray of GA3 stimulates to form lateral bud and increases the number of cloves per bulb. Growth regulators have a potential use for the substitute of the cold requirement of flowering bulbs and garlic [17-19]. In Iran fall planting is standard and common practice for garlic. Once planted, cloves sprout, then overwinter in the field and continue to grow in the early spring. Bulbs usually mature as plants senesce in mid spring (in Tarom regions, that have subtropical conditions). Some environments in Iran are not favorable for fall planting. These areas often are very cold, windy and snowy in fall and winter, making them difficult to manage, so agricultural practices are impossible. Introduction of some clones that genetically can produce normal bulbs in controlled conditions as greenhouse is one of the most important programs to increase garlic production. Many studies have indicated that the growth conditions can affect the growth and development of bulb crops but a little information is available for effects of genetic behavior on cloving and florogenesis [20]. Information on Iranian greenhouse planted cultivars and their requirements for improved cloving and higher bulb yield is lacking. The present study therefore examined the bulbing of some Iranian garlic cultivars in greenhouse conditions.

Materials and Methods

Plant Material

The experiment was conducted at the research greenhouses of Research Institute of Modern Biological Techniques (RIMBT)–University of Zanjan, Zanjan. Thirty-eight garlic cultivars (Tables .1 &2) were collected from important garlic producer provinces and stored under same conditions (4 °C). Prior to planting, one bulb (clone) selected from every cultivar randomly and garlic bulbs were split into the individual cloves (propagating material) and sorted same weight cloves (5 g) to culture. Cloves were soaked in water overnight to promote early sprouting before planting on the next day. The cloves were planted in medium pots (30×30 cm - 3 cloves per pot in 3 replications) including 2:1:1 ratio of field soil, sand, and rotted manure in control conditions (average temperature: 20 °C and 60 % RH) in the early of autumn of 2015. After growing the plants, a garlic seedling was kept in a pot. The pots were irrigated after planting to provide good clove-soil-water contact and after irrigation were done once a week by using a manual sprinkler. Weed control was manual. Bulbs were harvested when the leaves had turned pale green and started falling.

Data Collection and Statistical Analysis

Genotype effects on cloving and bulb yield of garlic were evaluated by determining the number of cloves/bulb, mean clove weight, mean bulb circumference. Randomized complete block design with 3 replications was used as statistical design.
The results of the experiment were statistically analyzed by ANOVA with the software SPSS – program and means were separated using Least Significant Differences (LSD) with $p \leq 0.05$ [21].

Results and Discussion

Influence of the Genotype on Garlic Greenhouse Bulbing.

Observations made regularly during the growing stage (Fig. 1) explained strong differences of growth linked to the varietal group of the tested cultivars. The size of bulb, number of cloves and fresh weight of bulbs were compared (Tables 1 & 2). Although all 38 parental grown cultivars in greenhouse were multiple cloves before planting, but only few cultivars have produced multi cloves (normal bulbs) under greenhouse conditions. Two classes of garlic cultivars were observed. Class A including 26 cultivars (Table 1) formed only single clove that their weights were varied between 7 to

25.27g. Class B including 12 cultivars presented significant differences in the number of harvested bulbs (Fig. 3): The cultivar of Zanjan had the biggest bulbs (65 g in average), and others (Tarom 9, Tarom 14 & Hamadan1-5) were intermediate (bulbs of 40 g in average). The semi bulbing characteristic was observed in some of cultivars (Fig. 2).

The regulation of bolting and bulbing is composed of complicated processes created by an intricate network of signaling pathways [21].

Fig. 1 Garlic grown in greenhouse, two months after planting.

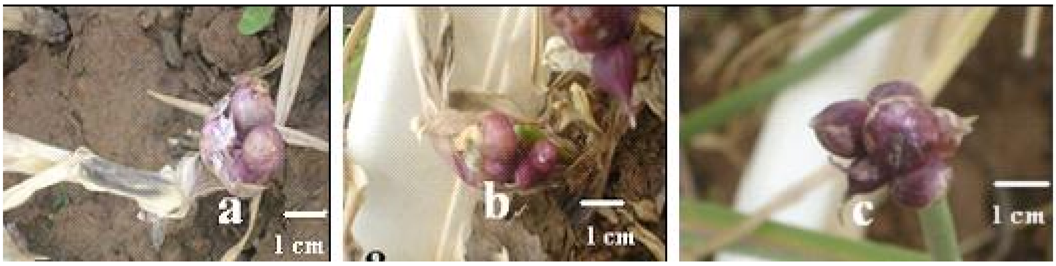

Fig. 2 The semi bulbing cultivars, bulbing on different parts of plant (a:rot, b & c stem end part).
Average weight of these semi bulb were 1-2 g

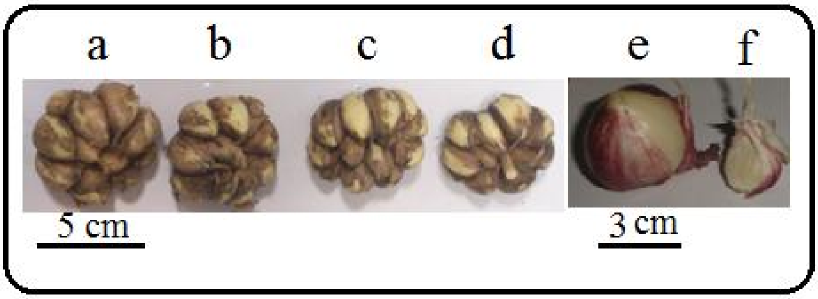

Fig. 3 Samples of multi cloves bulbs (right: a-d) and two single clove bulbs (e & f).

Table 1 Analysis of variance for 26 single clove cultivars, (w:weight, c: circumference)

Source	df	MS_W	MS_C	F-Value $_W$	F-Value $_C$	P-Value $_W$	P-Value $_C$
Cultivar	25	120.647	30.14	1545.22	629.53	0.000^{**}	0.000^{**}
Block	2	1.104	0.33	14.14	6.97	0.000^{**}	0.002^{**}
Error	49	0.078	0.047	-	-	-	-
Total	77	-	-	-	-	-	-

Table 2 Harvested data are presented for 26 garlic cultivars that were planted in greenhouse. Numbers in the same column followed by the same letter are not significantly different

Cultivar	Bulb/clove weight(g)	Circumference (cm)	Num. of clove per bulb	Size (grade)*
Ghaemshahr1	25.1 a	12 a	1	L
Ghaemshahr2	24.5 a	12.5 a	1	L
Ghaemshahr3	25 a	12 a	1	L
Ghaemshahr4	26 a	13 a	1	L
Ghaemshahr5	25.7 a	12.3 a	1	L
Tarom1	13.1 b	6 b	1	M
Tarom2	13 b	6 b	1	M
Tarom3	14 b	6.2 b	1	M
Tarom4	14.2 b	6.3 b	1	M
Tarom6	13.5 b	5.9 b	1	M
Tarom7	14.6 b	6.5 b	1	M
Tarom8	13.4 b	6 b	1	M
Tarom10	13.4 b	6.1 b	1	M
Tarom11	14 b	6.3 b	1	M
Tarom12	12.9 b	6 b	1	M
Tarom13	13 b	6 b	1	M
Auto1	8.3 c	4 c	1	S
Auto2	8 c	3.5 c	1	S
Auto3	7.2 c	3 c	1	S
Auto4	6.8 c	3 c	1	S
Auto5	7.4 c	3.5 c	1	S
Gilan1	8 c	4.3 c	1	S
Gilan2	8.2 c	4.4 c	1	S
Gilan3	8 c	3.6 c	1	S
Gilan4	7.5 c	3.6 c	1	S
Gilan5	7 c	3.2 c	1	S

*: L (large= ≥ 12cm in circumference), M: (medium=6-12cm) & S: (small = < 6 cm)

Table 3 Analysis of variance for 12 normal clove cultivars (w: weight, c: circumference)

Source	df	MS_W	MS_C	F-Value $_W$	F-Value $_C$	P-Value $_W$	P-Value $_C$
Cultivar	11	535.000	72.6591	1970.97	559.35	0.000**	0.000**
Block	2	0.181	0.4311	0.67	3.32	0.524	0.055*
Error	22	0.271	0.1299	-	-	-	-
Total	35	-	-	-	-	-	-

Table 4 Harvested data are presented for 12 garlic cultivars (multi bulbs) that were planted in greenhouse. Means and significant differences within each cultivar determined by ANOVA analysis. LSD mean separation tests were performed where significant differences were detected (ρ≤ 0.01). Numbers in the same column followed by the same letter are not significantly different.

Cultivar	Bulb/clove weight (g)	Circumference (cm)	Num. of clove per bulb	Size (grade)*
Hamadan1	40 b	20 b	9 b	M
Hamadan2	35 b	18 b	9 b	M
Hamadan 3	38 b	18.5 b	10 a	M
Hamadan 4	40 b	21 b	8 b	M
Hamadan5	39 b	20 b	9 b	M
Zanjan1	65 a	28 a	11 a	L
Zanjan2	64 a	29 a	10 a	L
Zanjan3	66 a	29 a	10 a	L
Zanjan4	63 a	27 a	9 b	L
Zanjan5	67 a	30 a	9 b	L
Tarom9	40 b	19 b	7 c	M
Tarom14	42 b	20 b	6 c	M

*: L (large=≥25 cm in circumference), M: (medium= 15-25 cm in circumference) & S:(small :< 15)

Vernalization fulfillment, followed by a higher temperature and long photoperiod is indispensable for garlic growth and development [22]. The interaction between temperature and photoperiod and the mechanism for bolting and bulbing have been key restrictions for the developmental regulation of garlic or the design of cultivation seasons and systems [23-24]. Although there are some drawbacks to spring planting (such as reduced yields) [25] or greenhouse planting, it may be an alternative during years in which fall planting is impossible. For spring planting to be successful, garlic bulbs must remain viable in storage conditions [19-32]. Our results about stable multiple cloves formation in some clones appeared to be strongly correlated with the garlic genotypes. Identification and assessment records revealed that two of four varieties of class B are multi cloves owned areas are planted in the spring such as Zanjan and Hamadan. Due to the cold weather conditions in autumn and winter in two Iranian provinces of Zanjan and Hamadan, the garlic is planted in the spring. In other words, these genotypes did not requires a lot of frost for bulbing and its development. Because the other two varieties (Tarom9 and Tarom 14) are planted in autumn, related of these characteristics to the growth habitat is unacceptable. Thus the work presented here aims at exploring the influence of both greenhouse conditions and genetic factor on quality of garlic bulbing.

Garlic genotypes differ considerably in scape length, flowering ability, seed production and other characteristics. The main edible parts of garlic are the bulbs, commonly known as cloves, which develop from axillary buds of the foliage leaves [19]. The bulbing and cloving in garlic are influenced by day length and the temperature to which the dormant cloves or growing plants are exposed before bulbing begins. Fall-planted garlic cultivars have higher clove number and higher overall productivity than spring-planted garlic. There is strong local demand for garlic for fresh market and processing use [26]. In addition, it would be desirable for growers to be able to sell garlic for fresh consumption especially for the most parts unavailable on the world market. To accomplish this, bulbing of garlic on greenhouse conditions must be studied and suitable genotypes (clones) introduced. The influence of environmental factors on bulb formation in garlic has been often reported. Temperature and day length have been demonstrated as key environmental factors for bulb induction [4-25]. Light spectrum quality is of primary importance for bulb formation in onion [26,27] but it has been stressed that day-length and tropic factors such as carbohydrates also affect the frequency of bulb formation in garlic [28]. Bulbing and cloving are two different development processes in garlic. Further studies are required to elucidate the factors affecting these two developments [28]. Our research findings demonstrated that bulbing of garlic can be done successfully in greenhouse depend on genotype. We identified 12 Iranian garlic clones for greenhouse planting which can produced normal and commercial multi cloves bulb successfully. Moreover 26 cultivars that produced single clove are most suitable for cooking usages due to easy skin peeling (Fig. 3.e-f.). It was evident that garlic genotypes vary significantly in response to photoperiod, temperature and that in some clones the greenhouse conditions enhances single cloving. The genetic variability acquired from sexual reproduction and vegetative preserved collections can serve in genetic and physiological studies as well as in breeding programs. A variation among garlic cultivars in bolting, bulbing and responses to environmental signals is expected and is most likely similar to what common occurs in other *Allium* plants [21-32]. The cultivars used in this research are widely cultivated in Iran due to their high yield of bulbs. Report of their greenhouse cultivated results is very important for selection of suitable genotypes for related conditions.

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